Climate induced changes along the West Antarctic Peninsula: Where have we been? Where are we going?

LTER Palmer has maintained a 17 year time series along the West Antarctic Peninsula

Current team

PI Hugh Ducklow (MBL)
Bacteria-Biogeochemistry

Bill Fraser (Polar Associates)
- Penguins & Fish

Karen Baker (Scripps)
- Data management
& Informatics

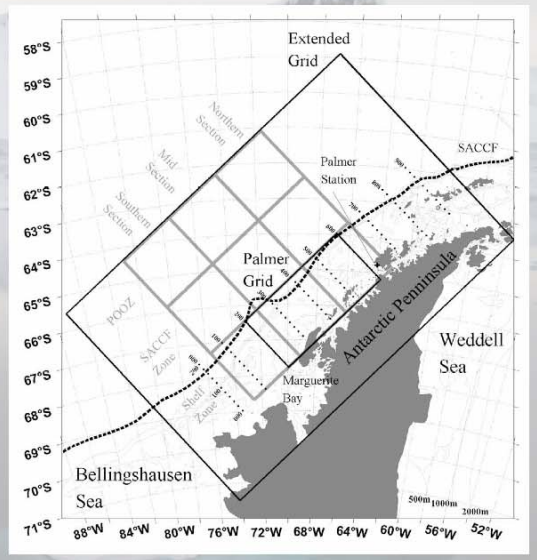
Scott Doney (WHOI)
- Ocean Modeling

Beth Simmons (Scripps)
- Education &
Outreach

Oscar Schofield (Rutgers) - Phytoplankton
Doug Martinson (LDEO) - Ocean Physics
Debbie Steinberg (VIMS) - Zooplankton

Sharon Stammerjohn (UCSC)
- Climate and Ice

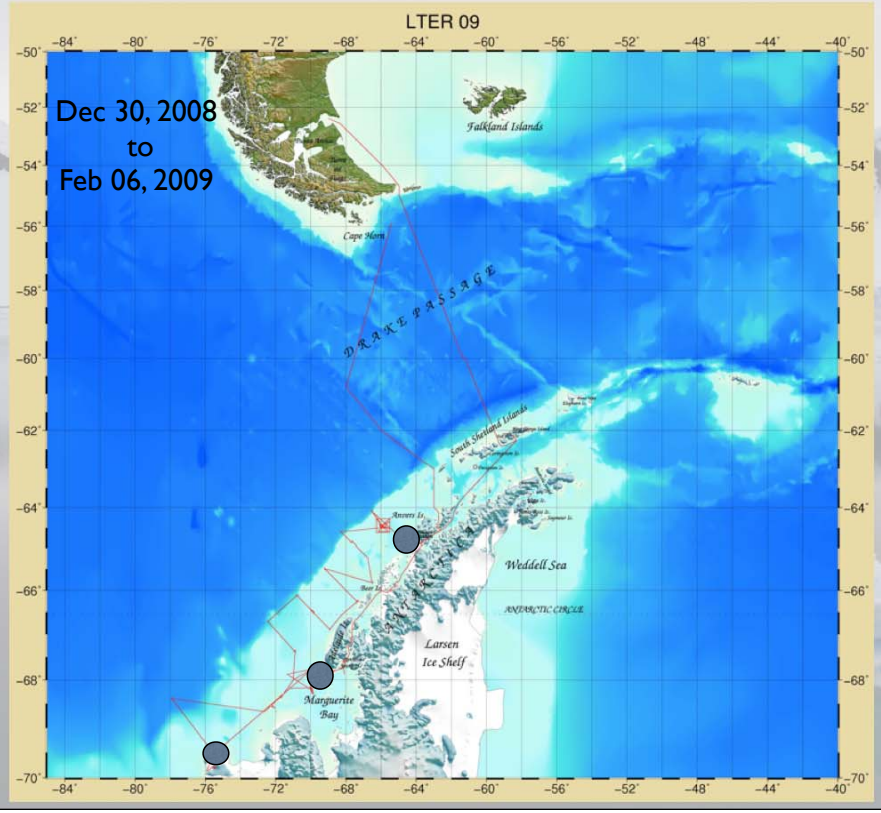
Our Current grid



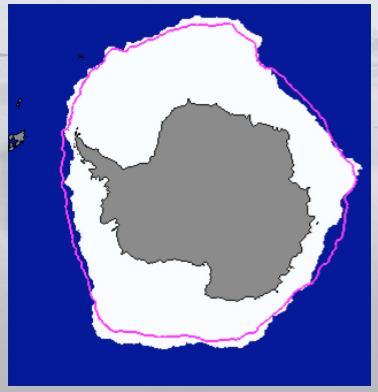
Acknowledgements to past LTER PIs: Ray Smith, Barbara Prezelin, Robin Ross, Langdon Quetin, Dave Karl, Maria Vernet, Eileen Hoffman, John Klinck

A rough day in the office

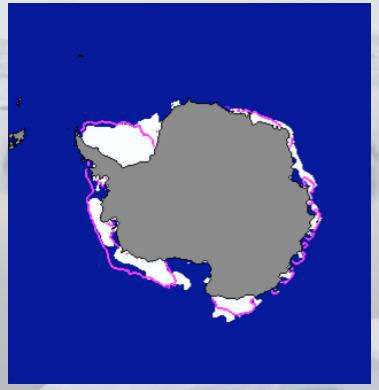
2009 represented the beginning of the next 6 year effort of the LTER. The grid has expanded to the south.



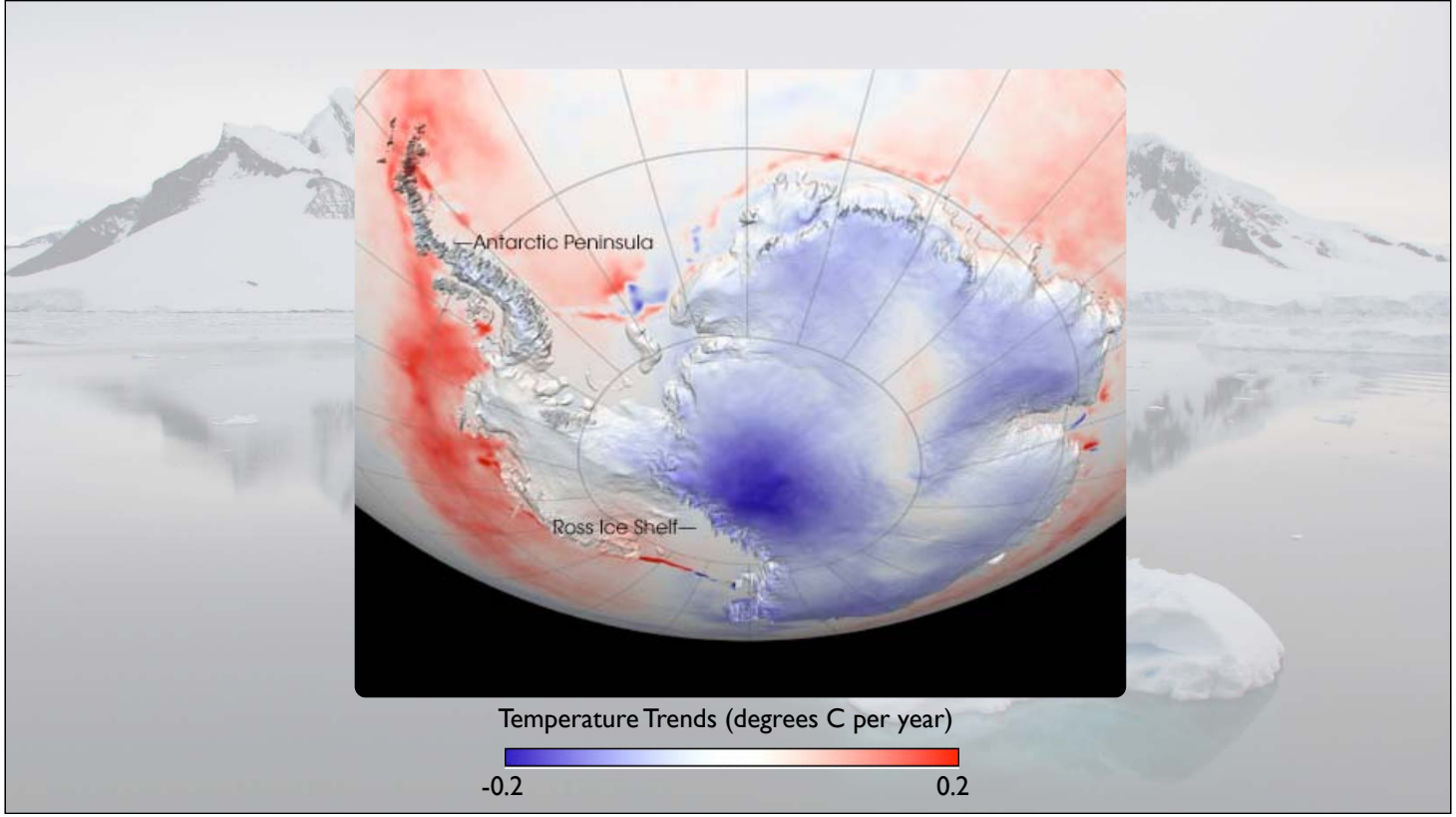
The central hypothesis when the LTER began was that sea ice timing and magnitude structure the productivity and composition of the Antarctic ecosystem. The ice dynamics are driven by large-scale interactions of the atmosphere and ocean.

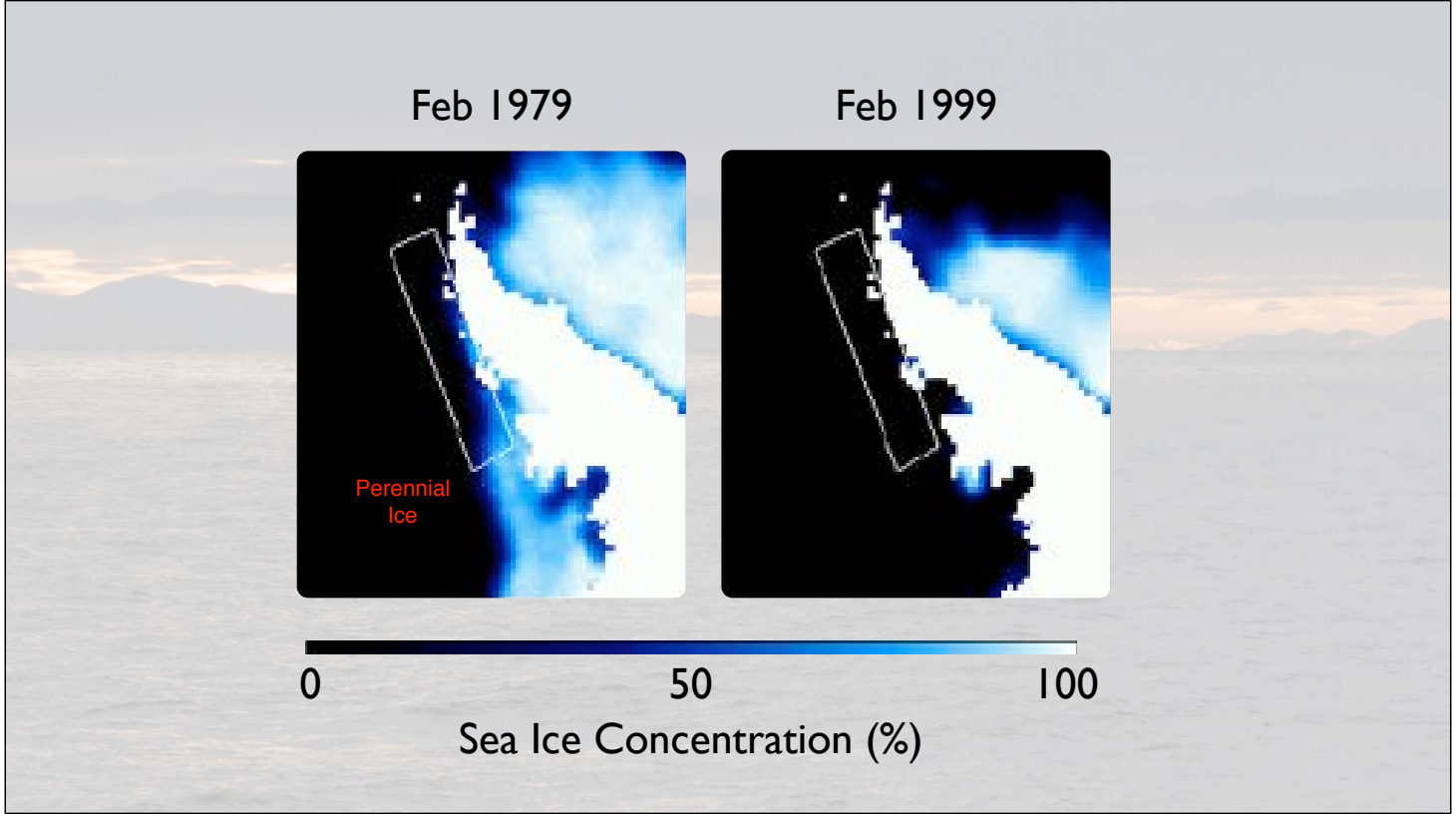


Winter 2007



Summer 2007

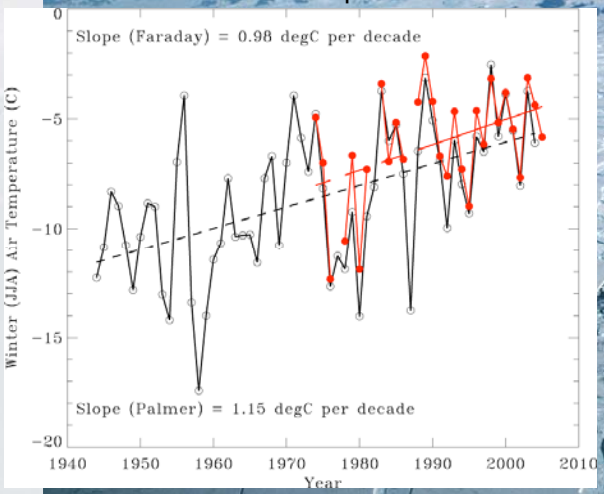

—Antarctic Peninsula
Ross Ice Shelf—
Temperature Trends (degrees C per year)
-0.2
0.2


Feb 1979
Feb 1999
Perennial
Ice
0
50
100
Sea Ice Concentration (%)

The WAP peninsula is experiencing the largest winter warming on Earth

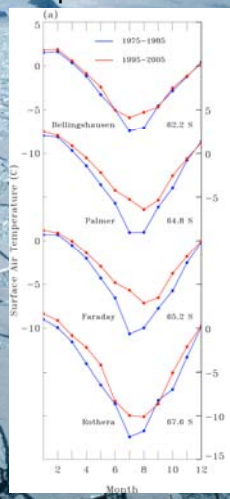
Larson-B ice shelf after its collapse
Thanks to BAS & A. Clarke

Mean Winter Temperatures

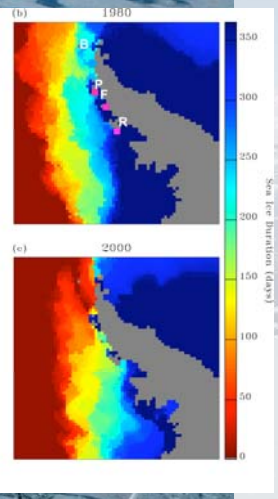


Black is British Faraday & Ukraine Vernadsky Station
Red is US Palmer Station

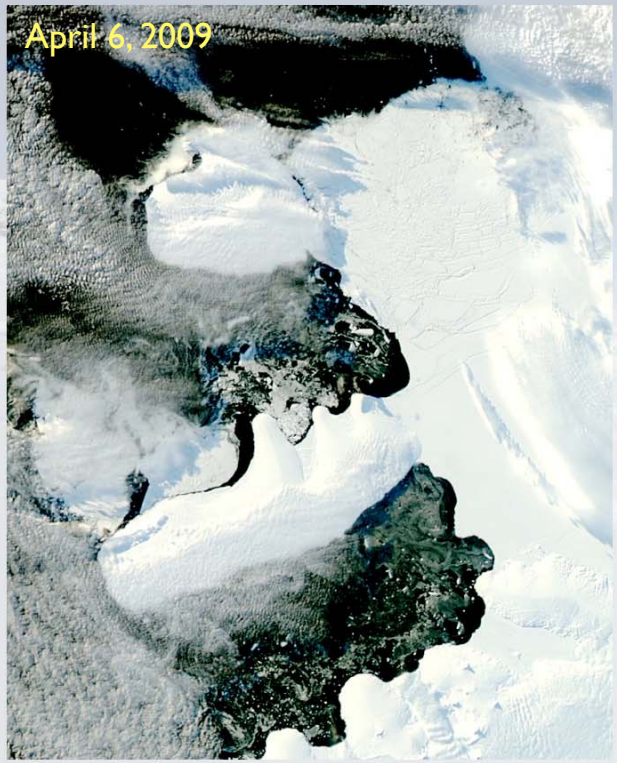
Air temperature increases over the peninsula

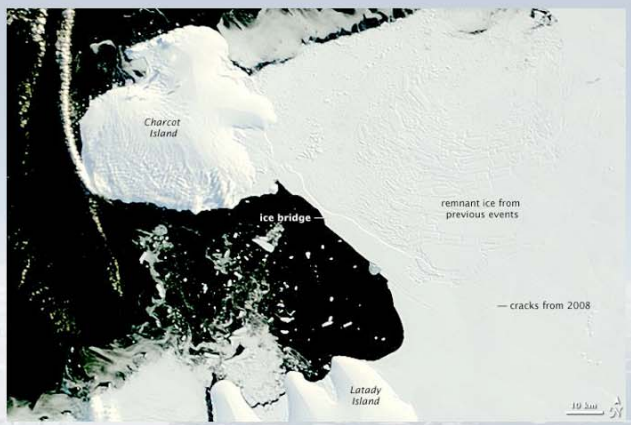


Sea ice duration drops



In 2008 the Wilkes Ice Sheet followed the Larson Ice Shelf and began to collapse



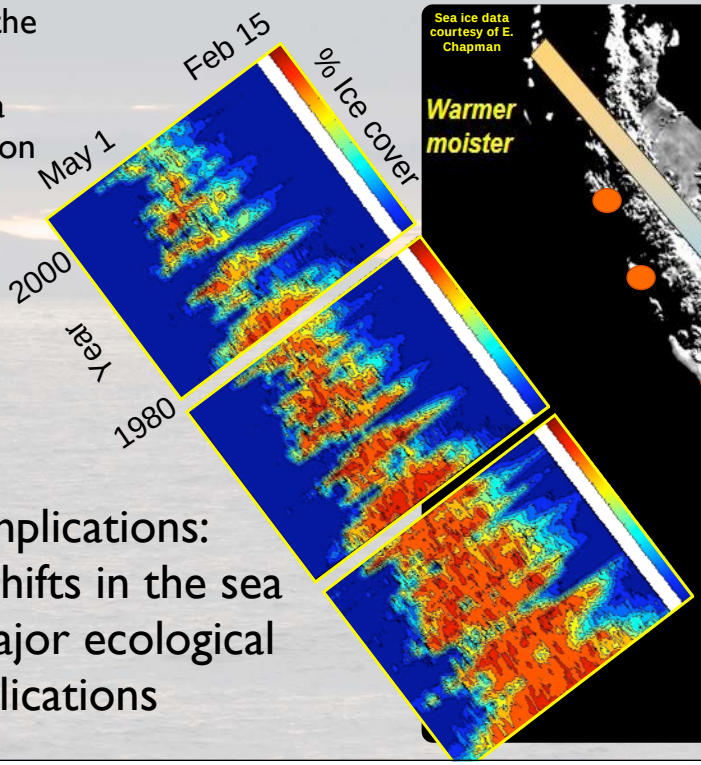


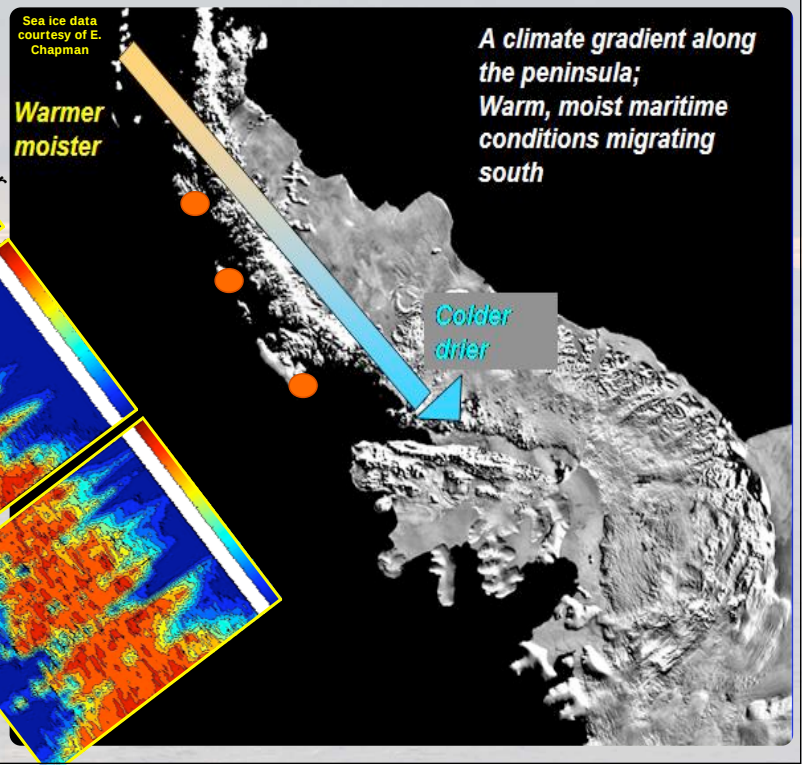
March 31, 2009

Melt pools on surface of King George VI Sound

(from a BAS twin otter, January 2004)

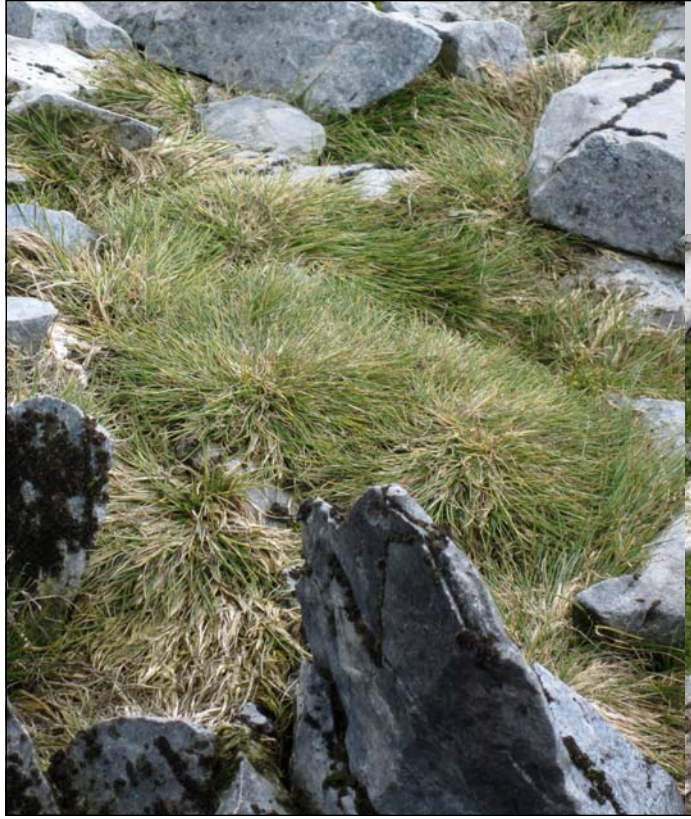
Seasonal ice has declined over the few decades resulting to a climate migration to the South





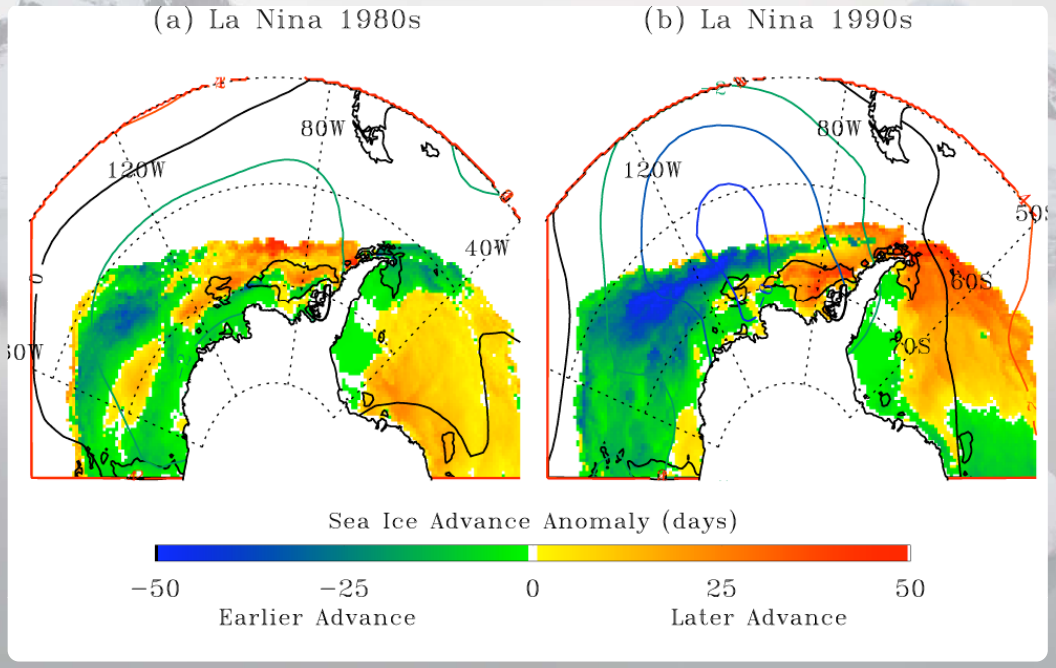
Key Implications: Regional shifts in the sea ice has major ecological implications


Palmer Station in the present
photo by Bill Fraser



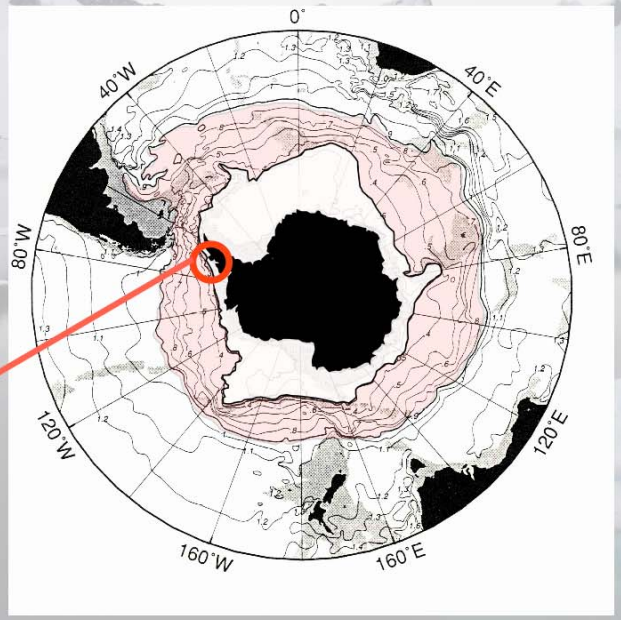
Plants at Palmer Station,
the greening of Antarctica

Interannual variability is complex due to interacting influence of the Southern Annular Mode and El Nino/La Nina

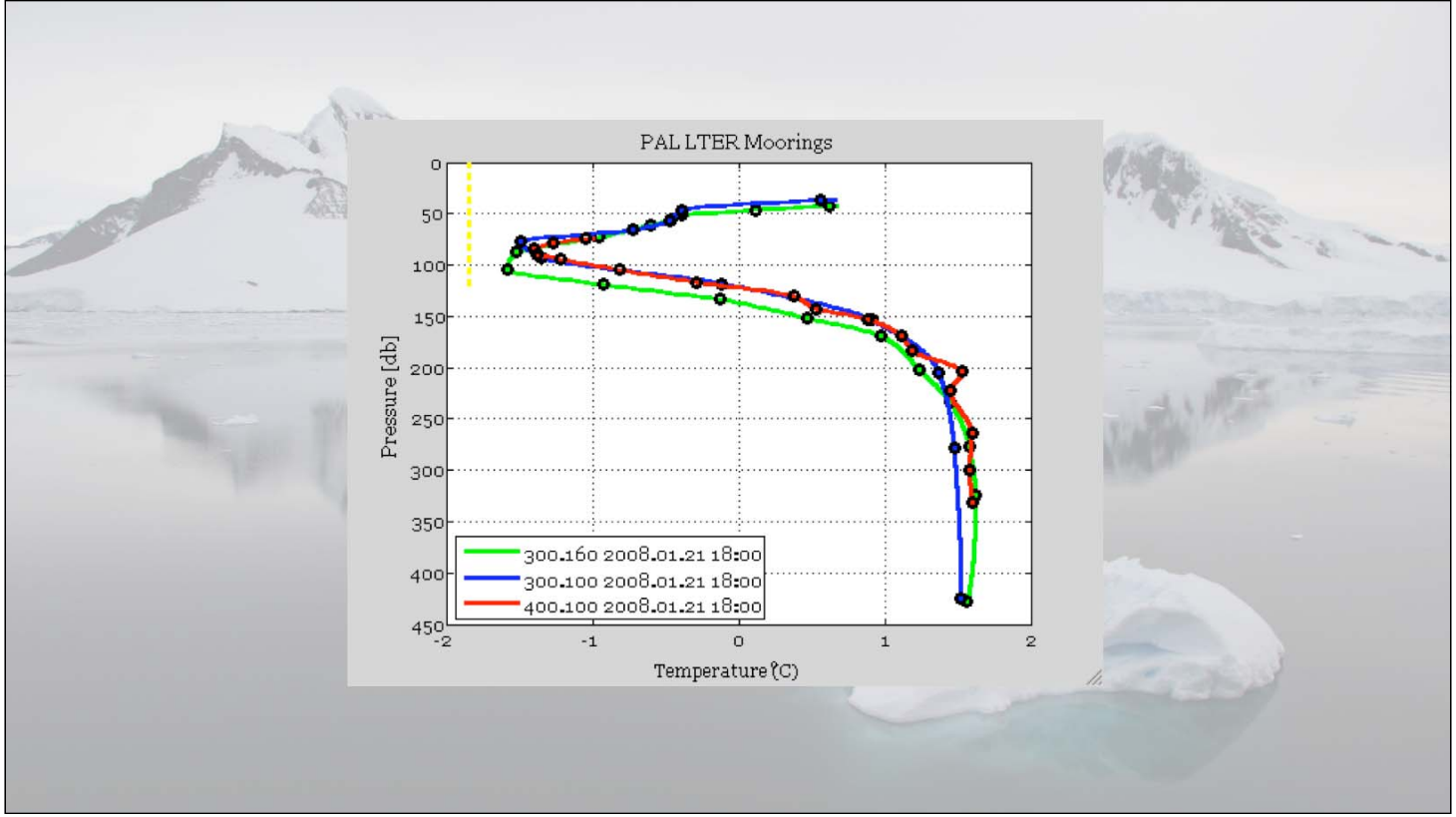


Stammerjohn et al. 2006

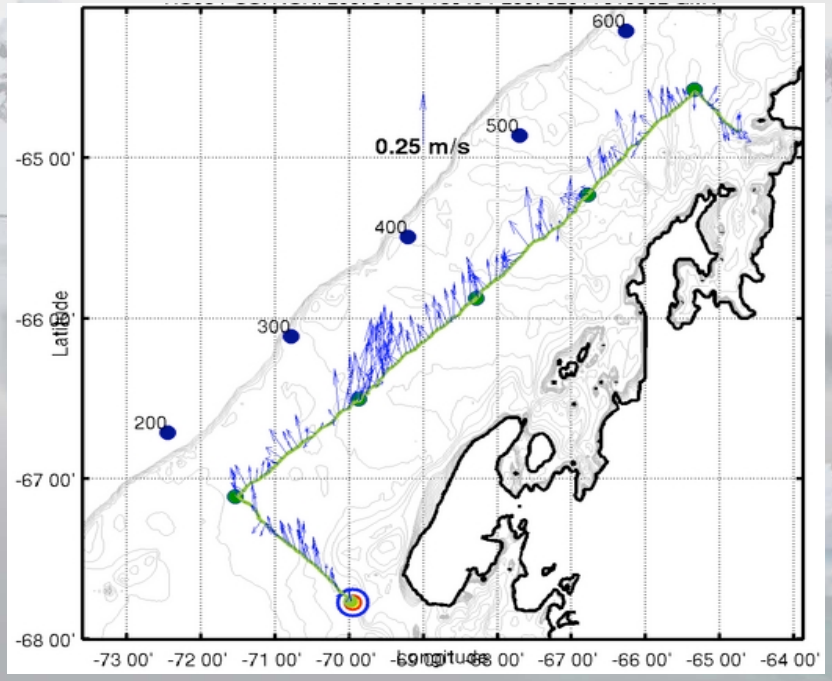
Heat input from Antarctic Circumpolar Current (ACC - world's largest ocean current = ~30,000 Niagara Falls). The heat is driven onto the shelf by intensification of upwelling-favorable winds.



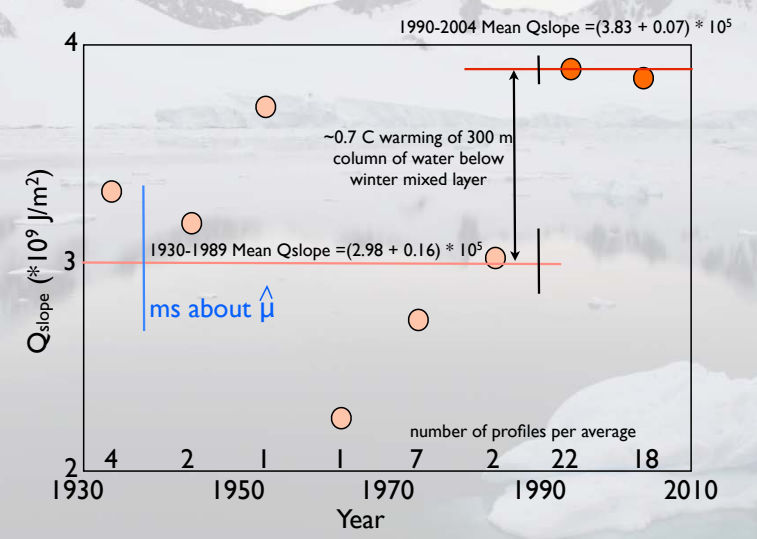
The WAP is the only location in the Antarctic where the ACC is adjacent to the shelf break. The ACC is Antarctica's warmest water


PAL LTER Moorings
Pressure [db]
Temperature (C)
0
50
100
150
200
250
300
350
400
450
-2
-1
0
1
2
300.160 2008.01.21 18:00
300.100 2008.01.21 18:00
400.100 2008.01.21 18:00

Upwelling favorable winds result in Ekman mass transport offshore

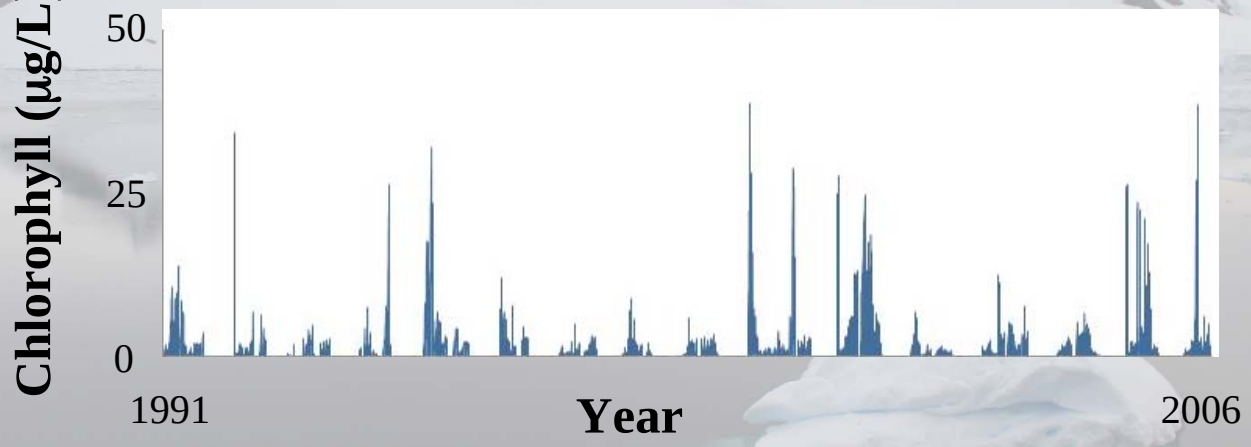


Heating on the WAP is driven by circulation and intrusion of the of the ACC onto the WAP continental shelf. Using decadal averages of the scant data, there was a jump after the year 2000.

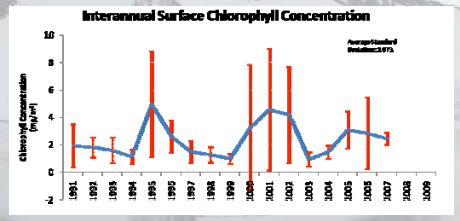


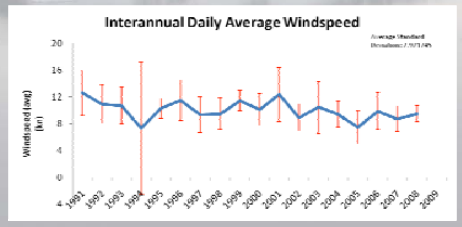
Thanks to Doug Martinson

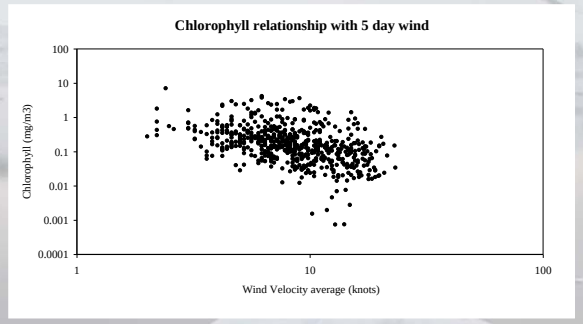
Palmer time series: Phytoplankton show large interannual variability



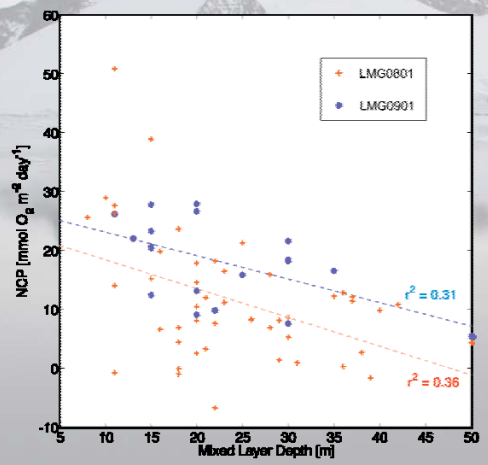
No strong correlations to seasonal meteorological data
Weak inverse relationship to the wind forcing the week prior



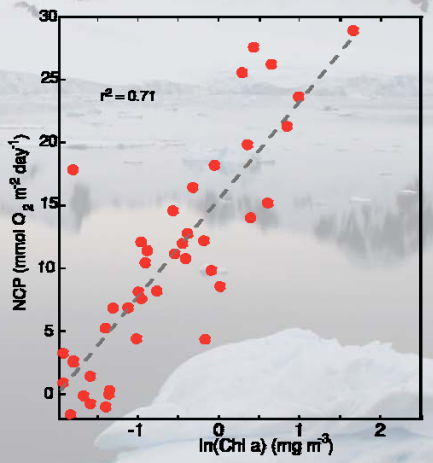




NCP from LMG0801 and LMG0901 is negatively correlated with the MLD

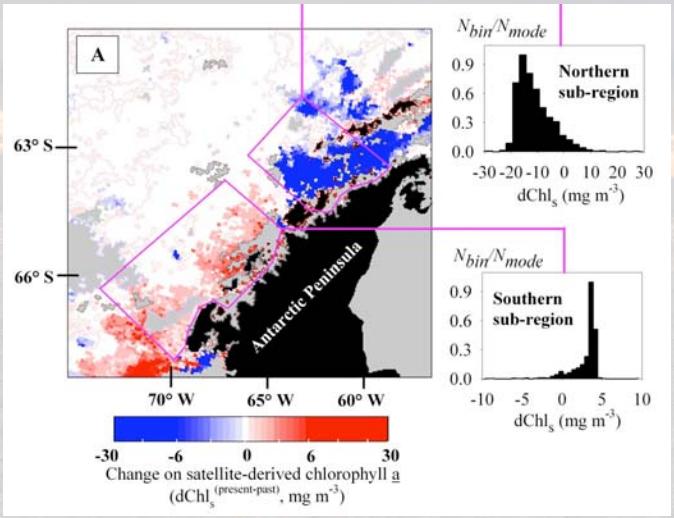


NCP from LMG0801significantly correlated with averaged chl concentration in the mixed layer

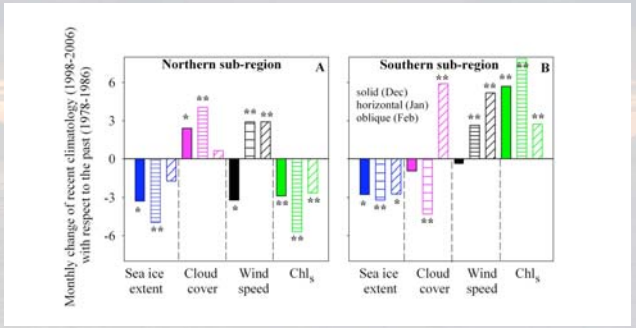


Huang & Bender

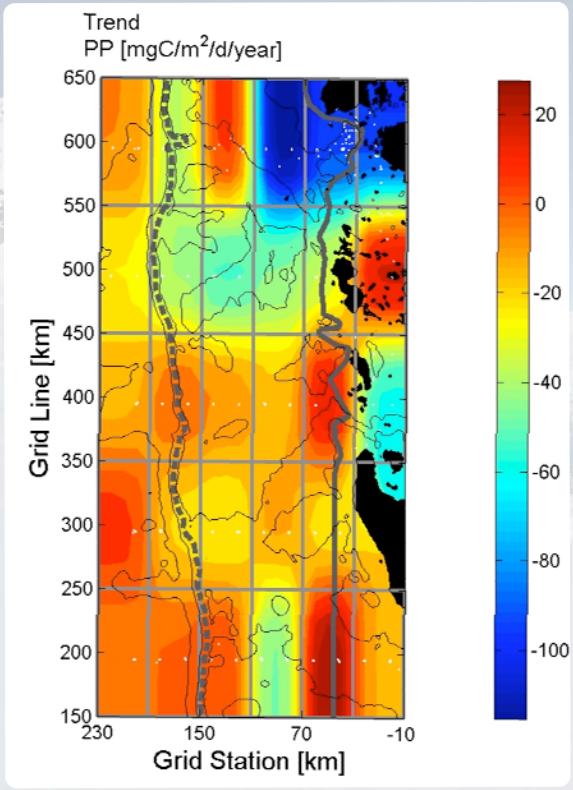
The decadal changes have resulted changes in the phytoplankton



Montes Hugo et al. Science 2009



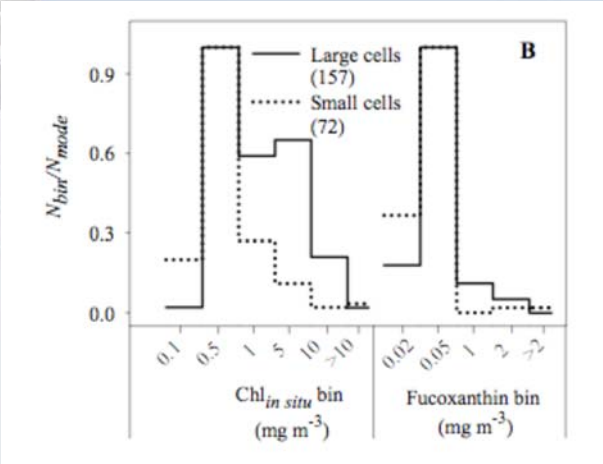
The changes driven by a decline in sea ice, wind and sun



15 year time series of radio-carbon measurements also suggest a North & South gradient

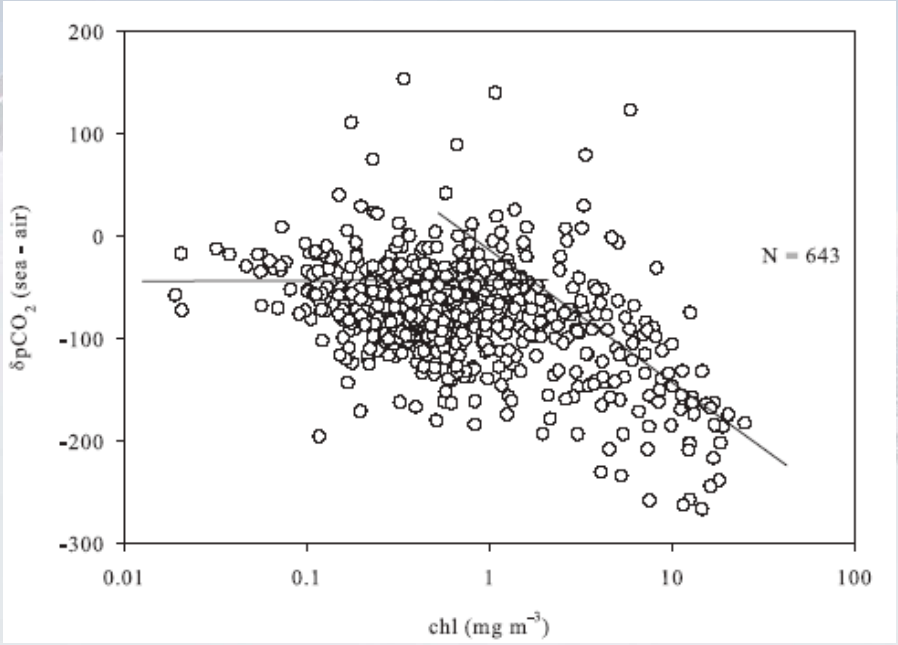
Vernet et al. DSR 2008

When chlorophyll is high, phytoplankton cells are big and are largely diatoms

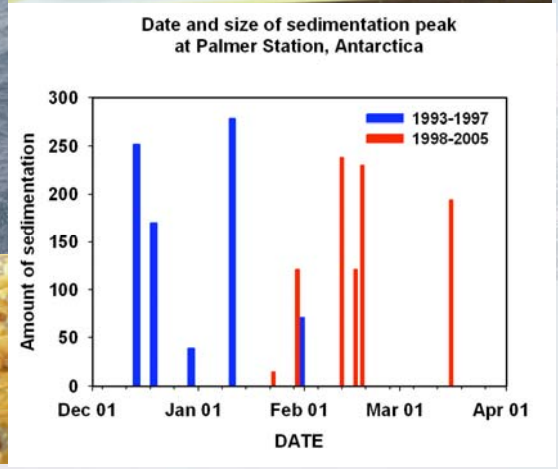


Montes Hugo et al. 2009

Change in biomass impact on biogeochemistry

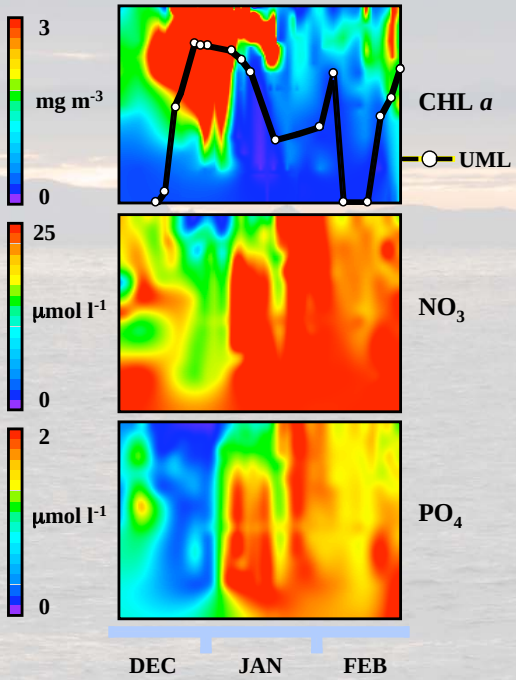


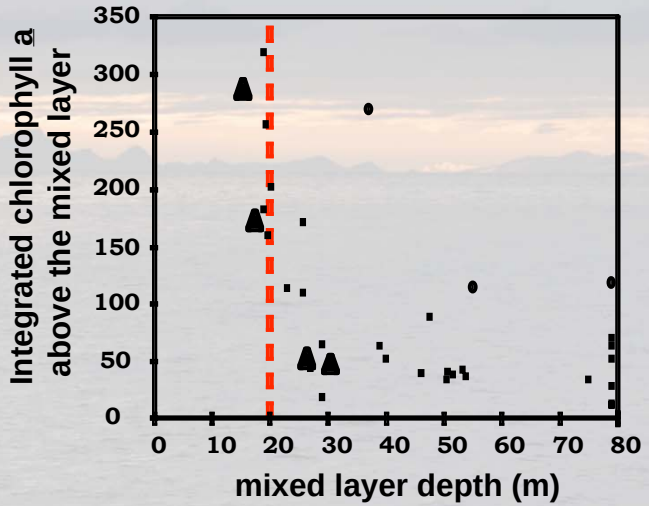
Export fluxes are episodic, show seasonal peaks, and appear to have changed



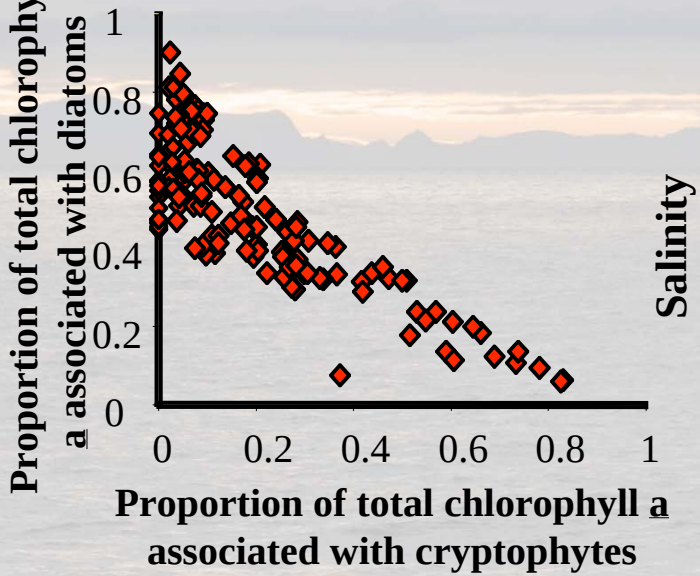
Ducklow et al. 2008

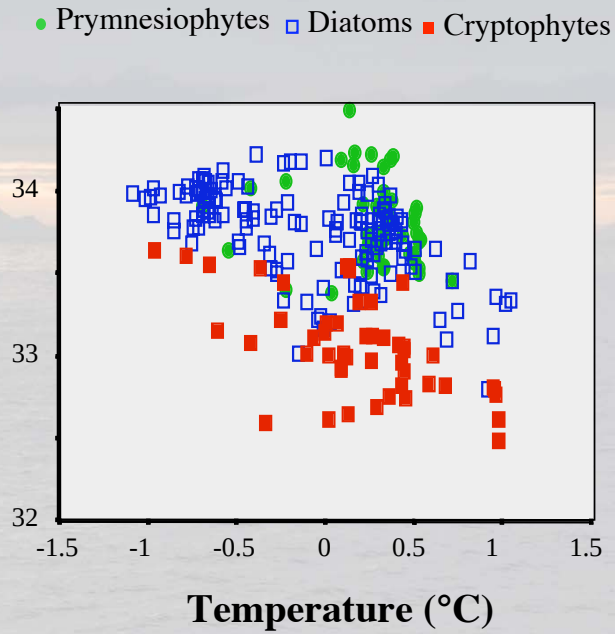
What regulates phytoplankton blooms in this region?



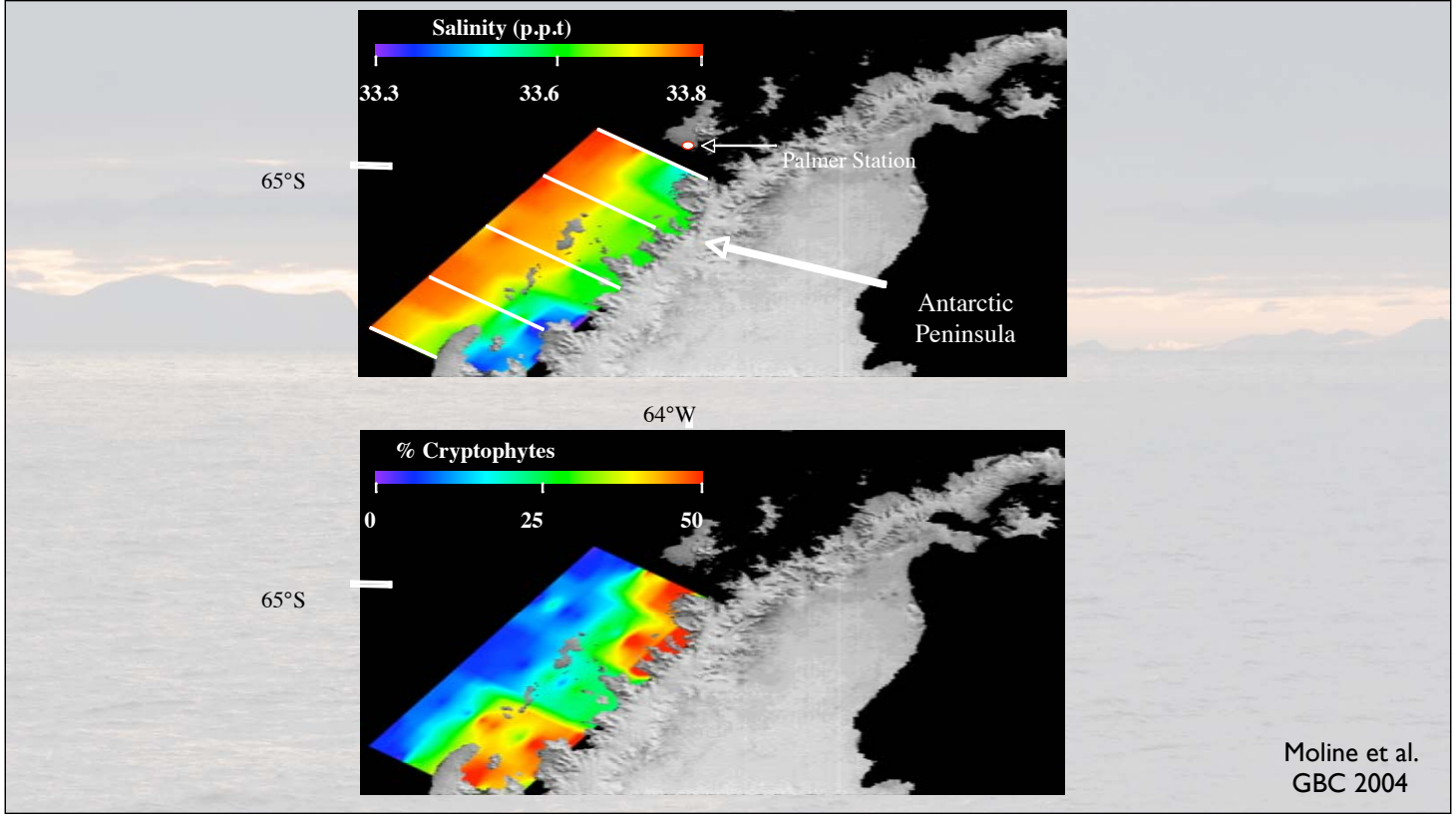


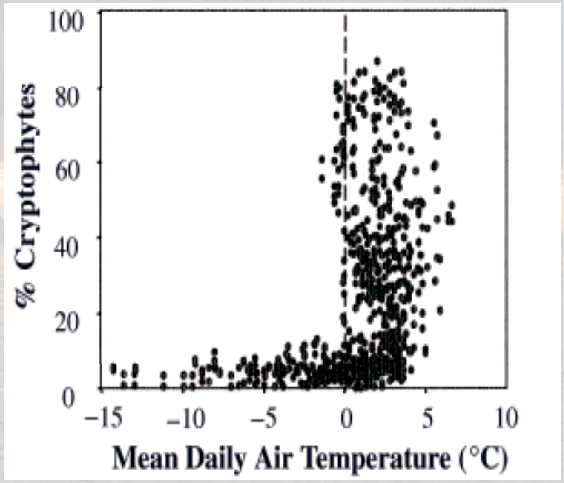
Who will dominate the warmer WAP?



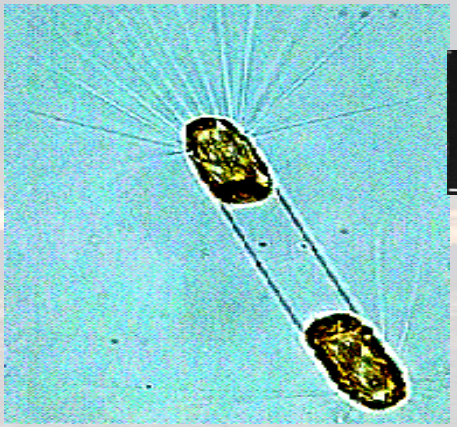


Moline et al. GBC 2004


Salinity (p.p.t)
33.3
33.6
33.8
Palmer Station
65°S
Antarctic
Peninsula
64°W
% Cryptophytes
0
25
50
65°S
Moline et al.
GBC 2004



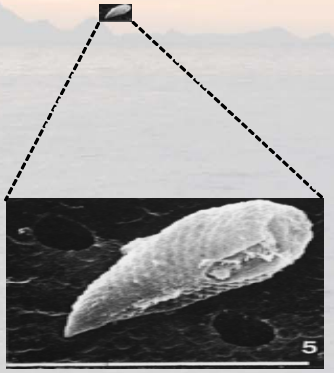
Moline et al.
GBC 2004



Corethron criophilum

100µm

Thalassiosira antarctica



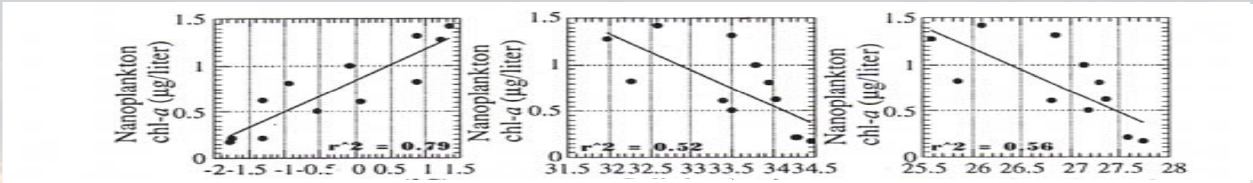
10µm

Cryptomonas cryophila

Palmer Cryptophytes --> 8 ± 2µm

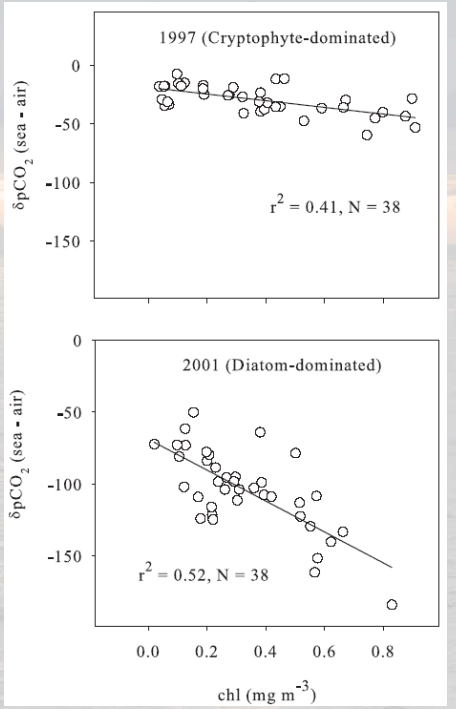
SEM Micrographs from*McMinn and Hodgson* 1993

A general feature in the warming WAP?



Location	Reference
South Shetland Islands	*V illafañe et al.*, 1995; *Kang, S-H et al.*, 1997; *Kang, J-S et al.*, 1997
Weddell-Scotia-Bellingshausen Confluence Areas	*Lancelot et al.*, 1991; *Nothig et al.*, 1991 *Tréguer et al.*, 1991; *Buma*, 1992; *Mura et al.*, 1995; *Kang and Lee*, 1995; *Aristegui et al.*, 1996
Ellis Fjord	*McMinn and Hodgson*, 1993
Bransfield Strait	*Kang and Lee*, 1995; *Kang et al.*, 1995
Historical Data	
Anvers Island	*Krebs*, 1983
Signy Island	*Whitaker*, 1982

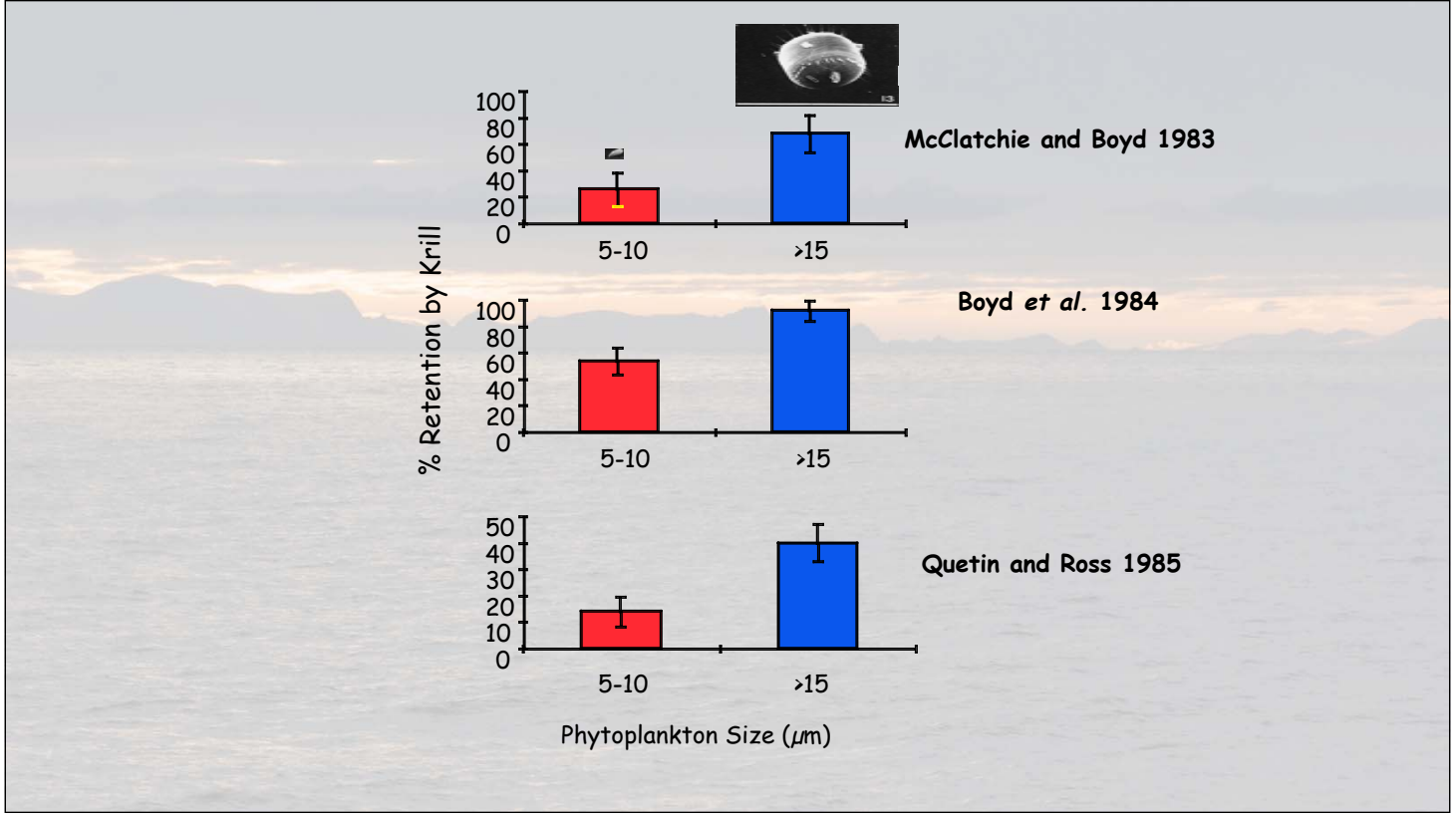
CO_2 uptake varies with phytoplankton community



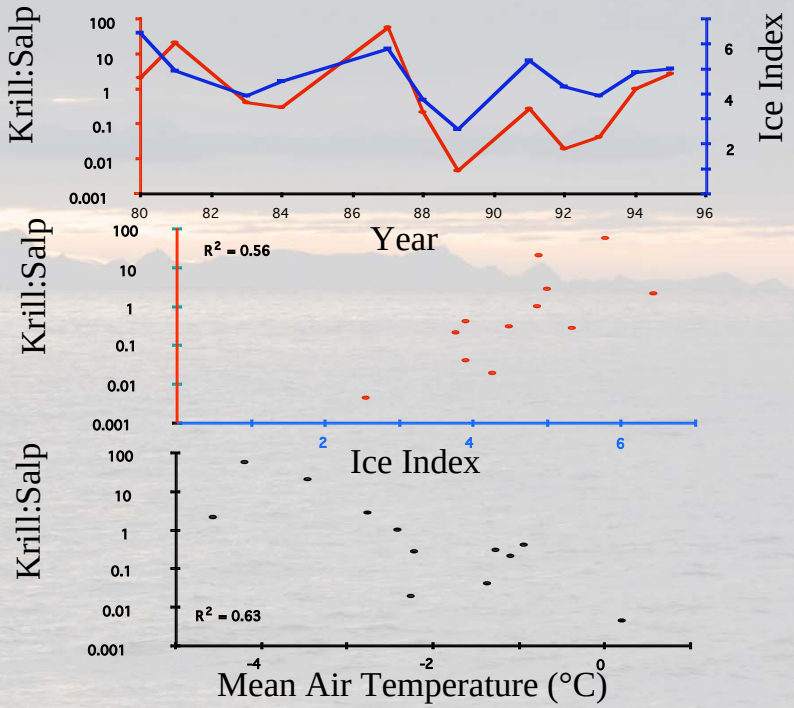
Montes Hugo in prep

Zooplankton are dominated by krill or salps

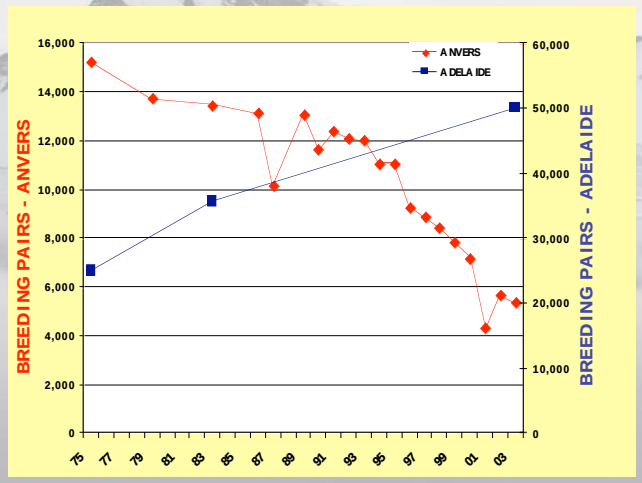
Krill greatest biomass of any animal on earth

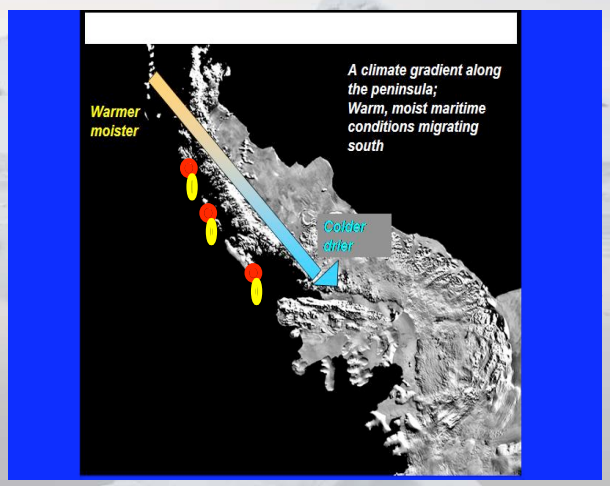

McClatchie and Boyd 1983
Boyd et al. 1984
Quetin and Ross 1985
% Retention by Krill
100
80
60
40
20
0
5-10
>15
50
40
30
20
10
0
Phytoplankton Size (μm)

From *Loeb et al.*, 1997



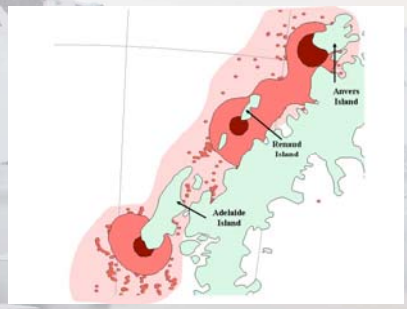
Is there an impact on higher trophic levels?


ANVERS
ADELAIDE
BREEDING PAIRS - ANVERS
BREEDING PAIRS - ADELAIDE
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
60,000
50,000
40,000
30,000
20,000
10,000
0
75
77
79
81
83
85
87
89
91
93
95
97
99
01
03

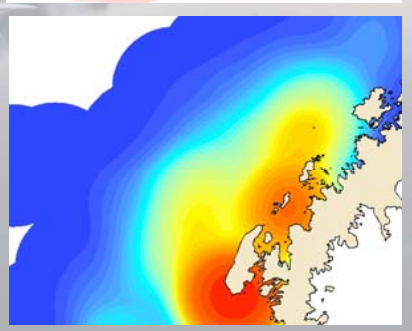

Warmer moister
A climate gradient along the peninsula; Warm, moist maritime conditions migrating south
Colder drier

One focus idea of the LTER is testing, is that system is undergoing climate migration. We have structured sampling around the major Adelie penguin breeding areas along the peninsula.

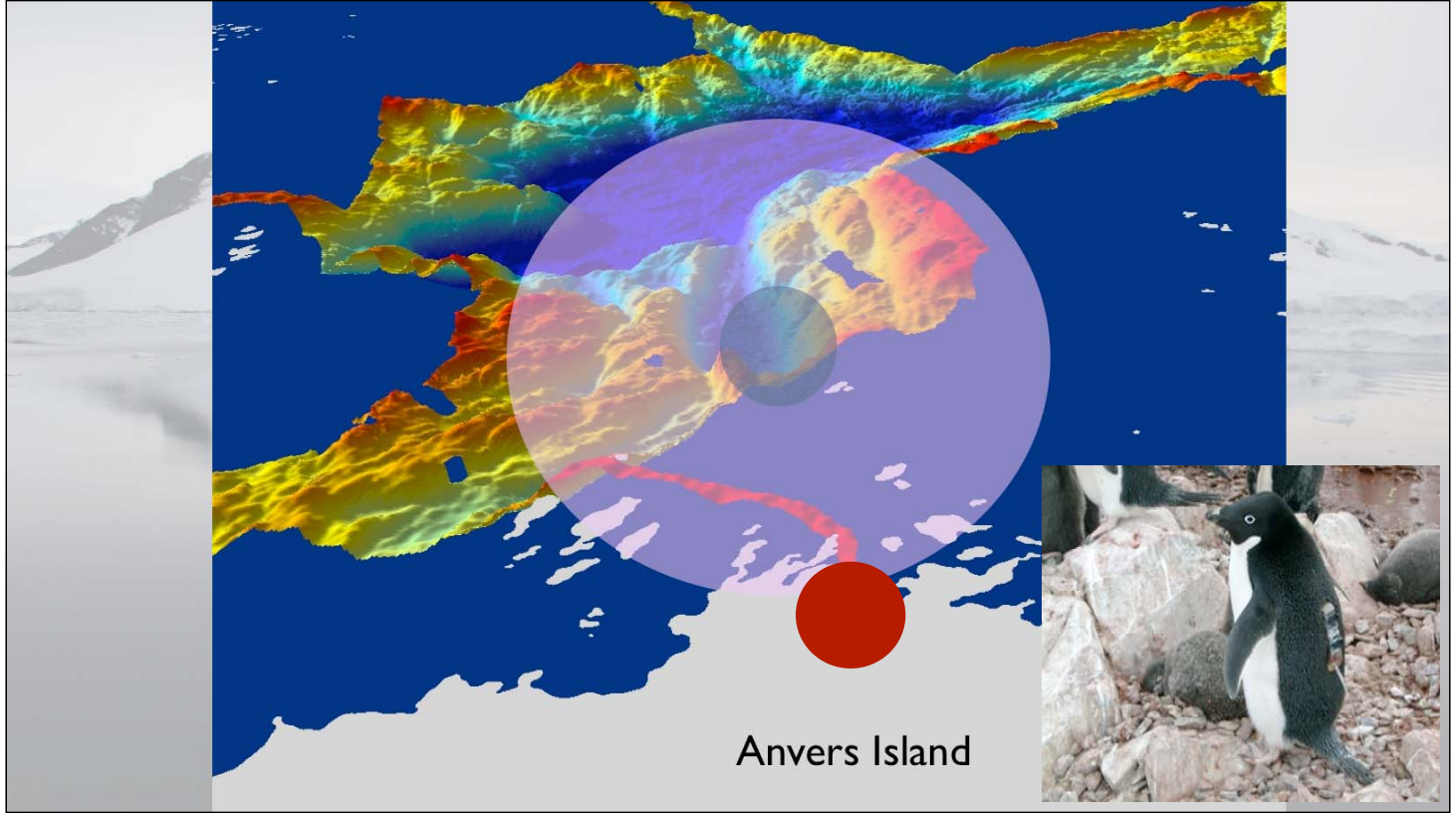
Summer foraging areas for Adelie penguins



Winter foraging areas for Adelie penguins



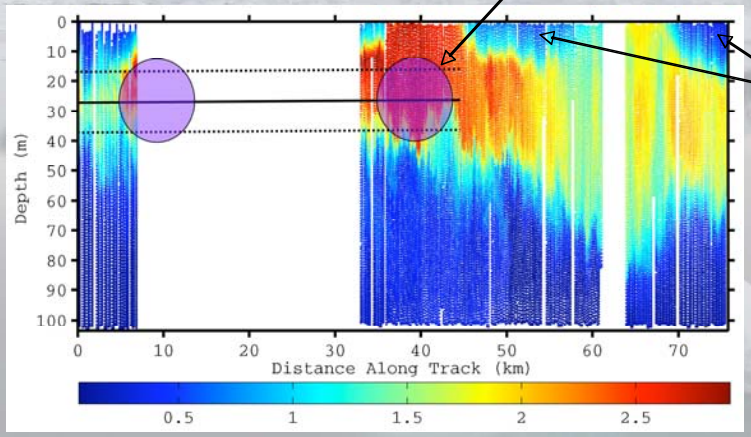
To be expanded by NASA grant awarded in Dec.


Anvers Island

The Adelie penguins feed during the daylight hours and are visual feeders and need to get back to the rookeries by nightfall, limits the foraging area to around ~50 kilometers. The penguins feed at the base of the chlorophyll maximum where water is clear.

Glider leaks, emergency recovery and repair (yikes!)

Radio-tagged foraging depths of Adelie penguins

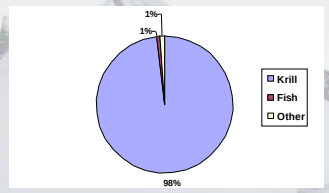


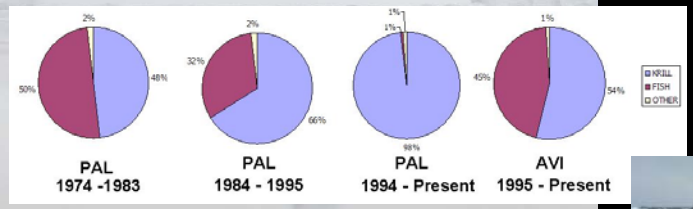
Solar quenching of Chlorophyll fluorescence

Chlorophyll (μg/L)

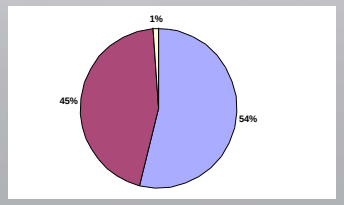
Changing diets for the Adelie penguins

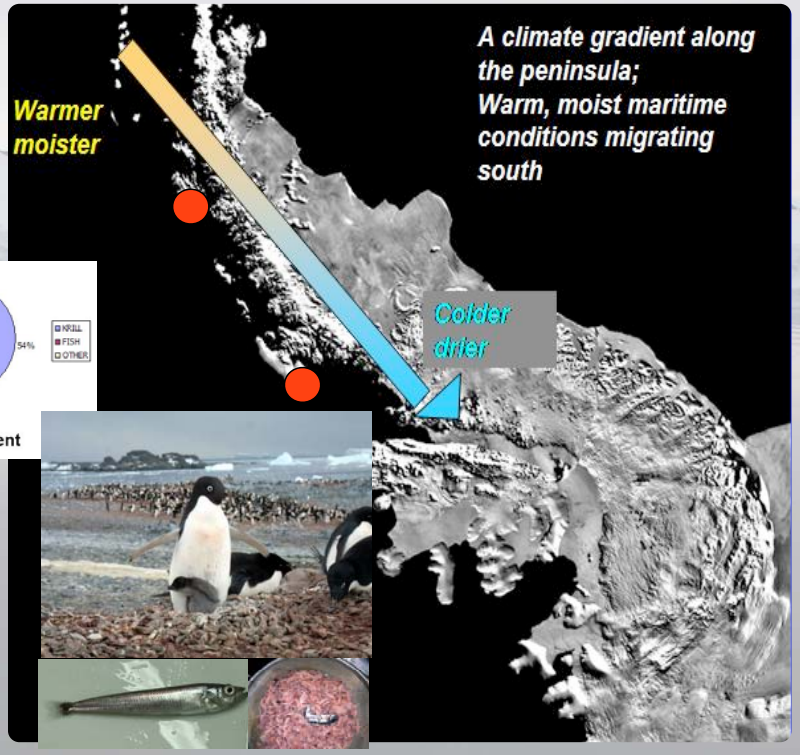
1994-present

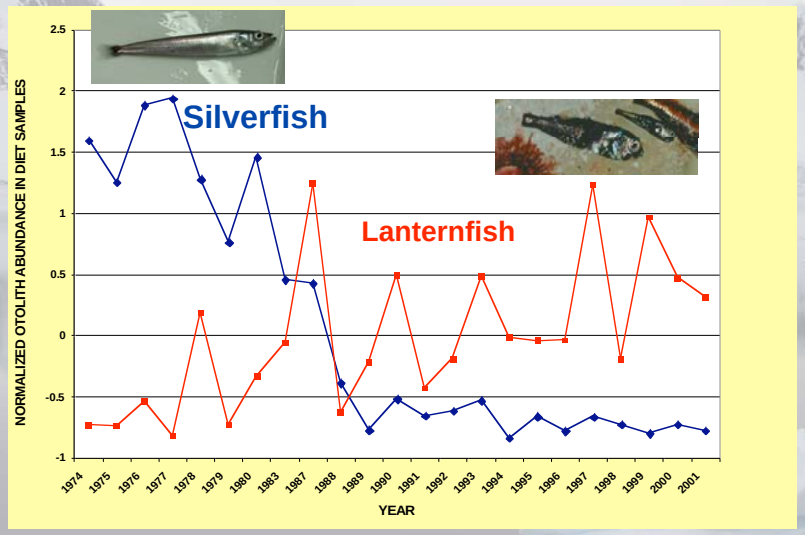




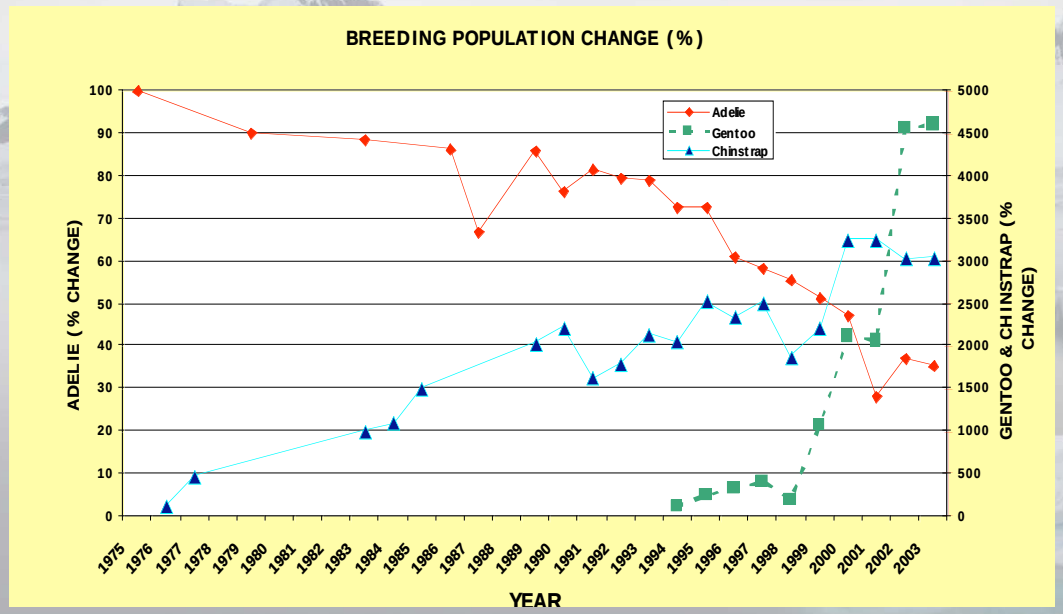
1995-present






Silverfish
Lanternfish
NORMALIZED OTOLITH ABUNDANCE IN DIET SAMPLES
2.5
2
1.5
1
0.5
0
-0.5
-1
1974
1975
1976
1977
1978
1979
1980
1983
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
YEAR

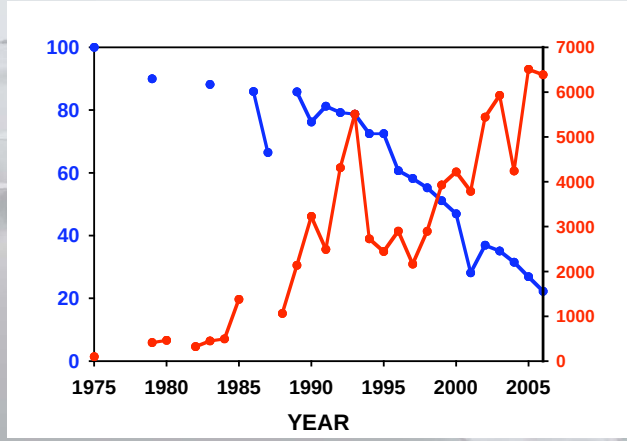
If that was not enough, warmer temps leads to more moisture and more snow. Breeding failure.....


BREEDING POPULATION CHANGE (%)
ADELIE (% CHANGE)
GENTOO & CHINSTRAP (% CHANGE)
YEAR
Adelie
Gentoo
Chinstrap
100
90
80
70
60
50
40
30
20
10
0
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003

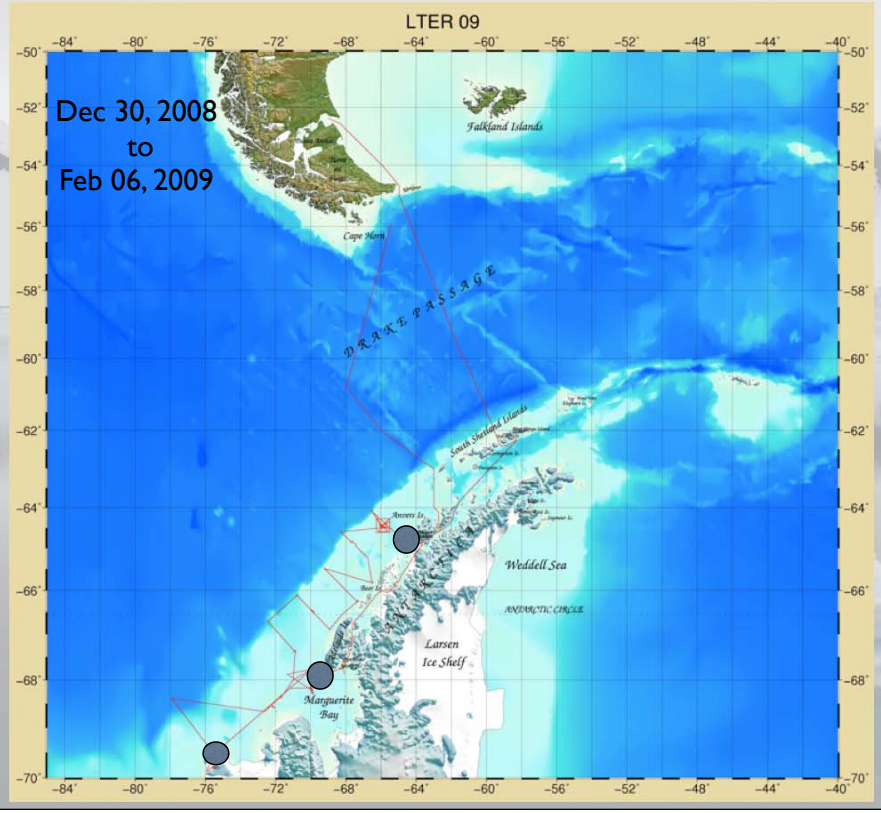
Where are we headed? We need your help to communicate what we find as it happens

Adelie penguins
Weddell seals

Chinstrap penguins
Gentoo penguins
Fur seals
Elephant seals



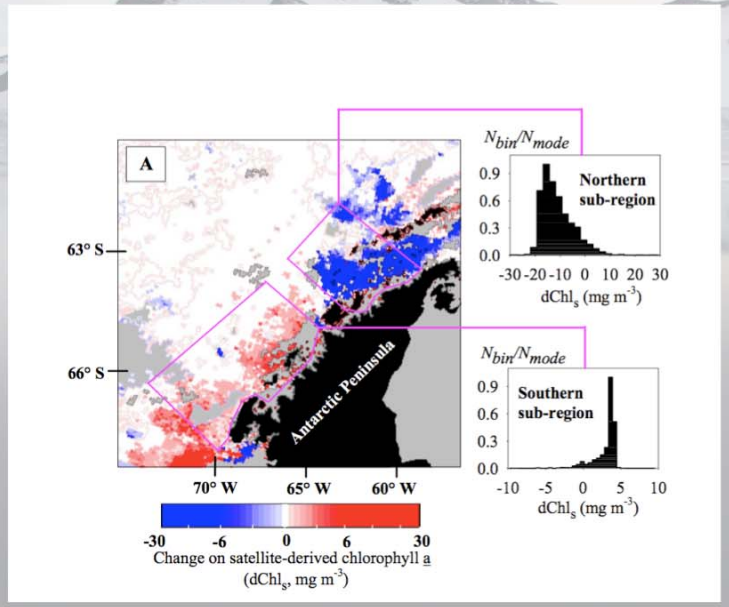
2009 represented the beginning of the next 6 year effort of the LTER. The grid has expanded to the south.



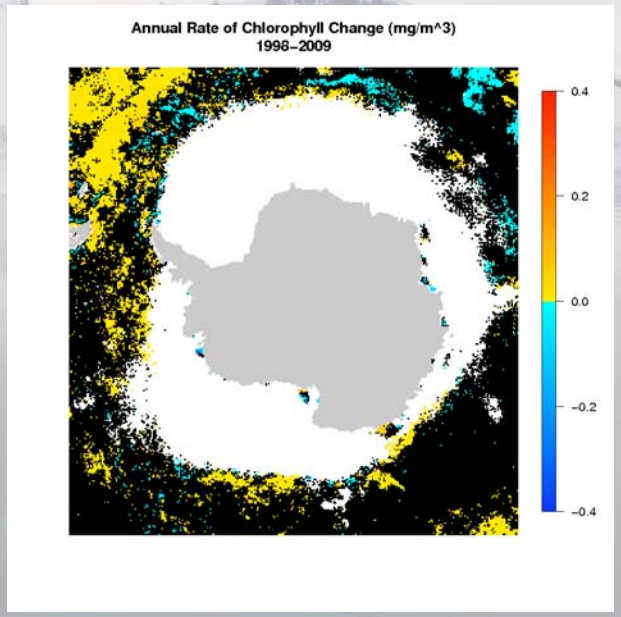
2009 LTER heads to Charcot to see if a penguin colony exists as predicted

Phytoplankton Dynamics

Over thirty years, we see large changes in phytoplankton productivity (overall decline)

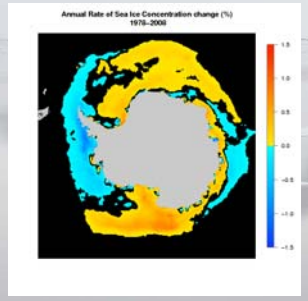


Over decade trends are less clear

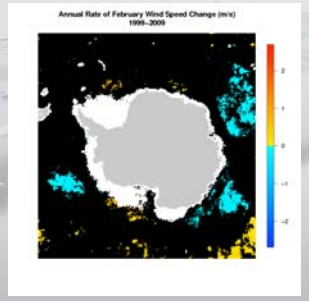


Development of GAM model for penguins rookeries. We analyze sea ice, wind, temperature, and chlorophyll in and around penguin rookery areas in WAP to determine which variables are most important for modeling the rookery environment.

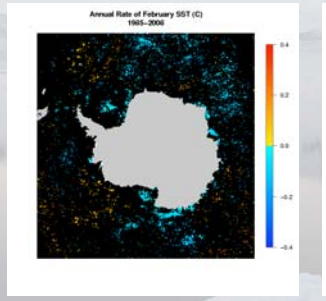
10 year analysis annual trends



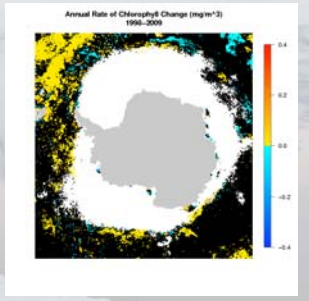
ice decline



wind no change

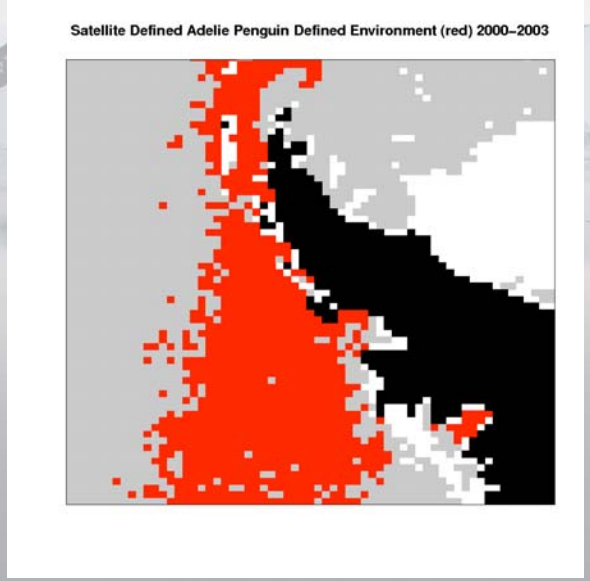


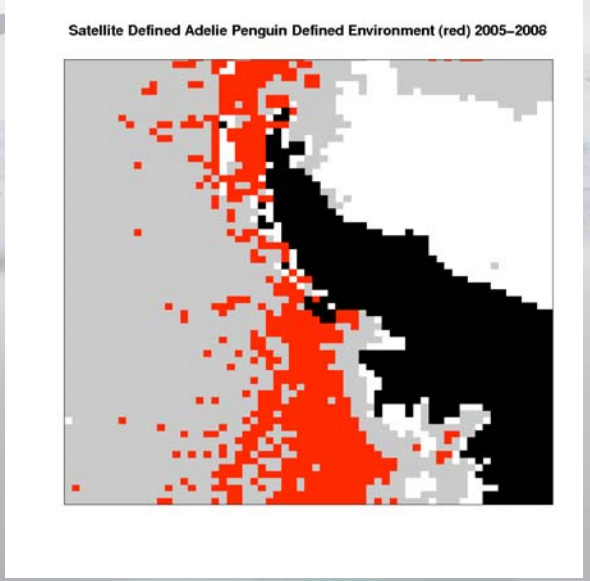
SST no change



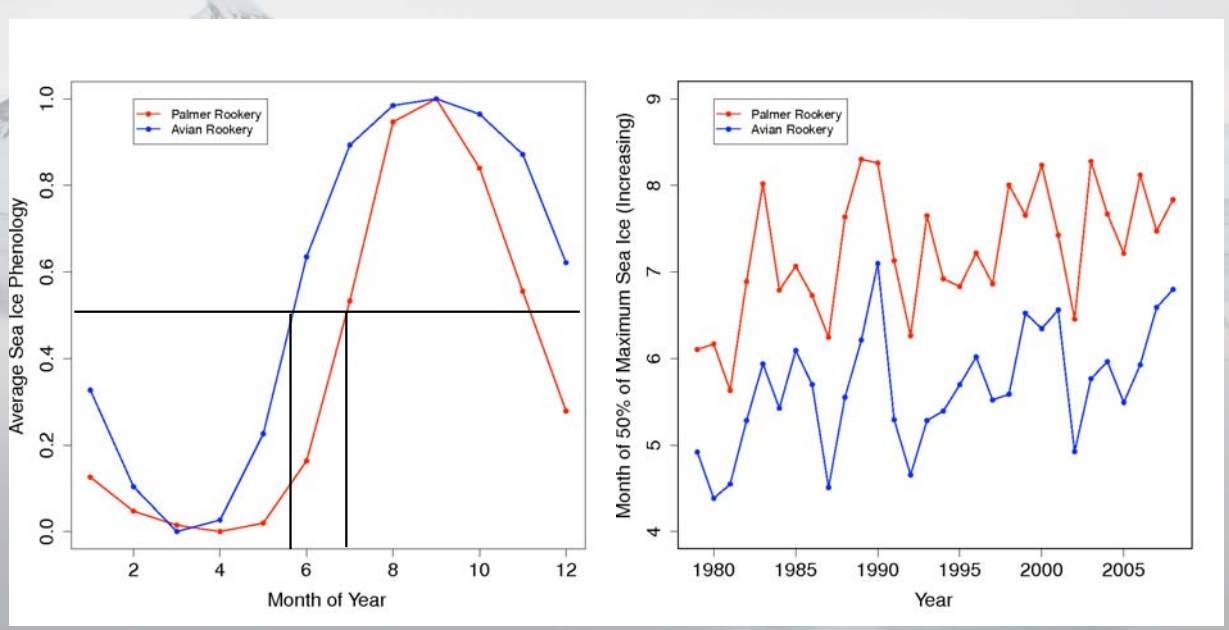
Chl hint increase

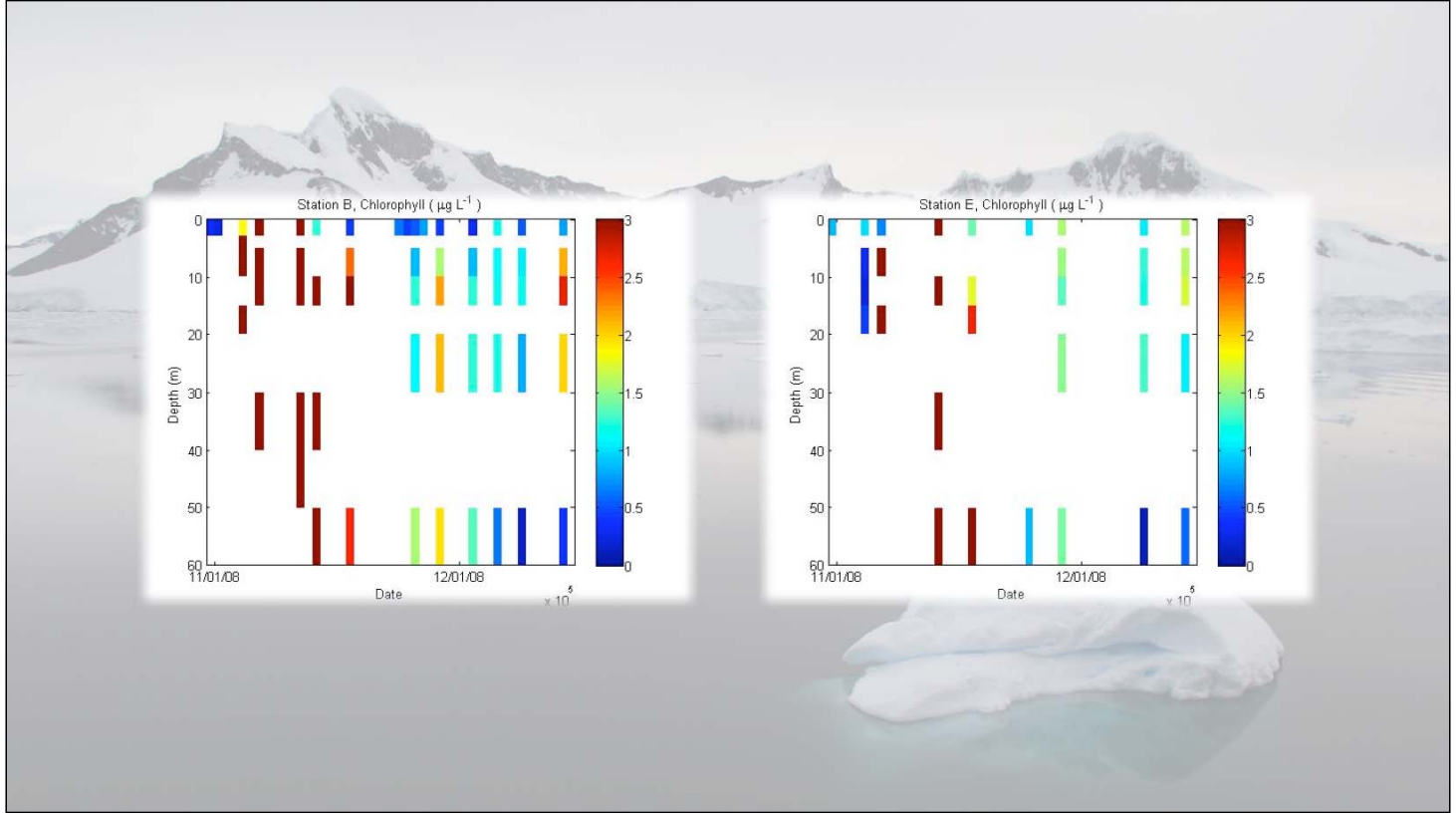
Results suggests the pelagic niche for the Adelie is changing

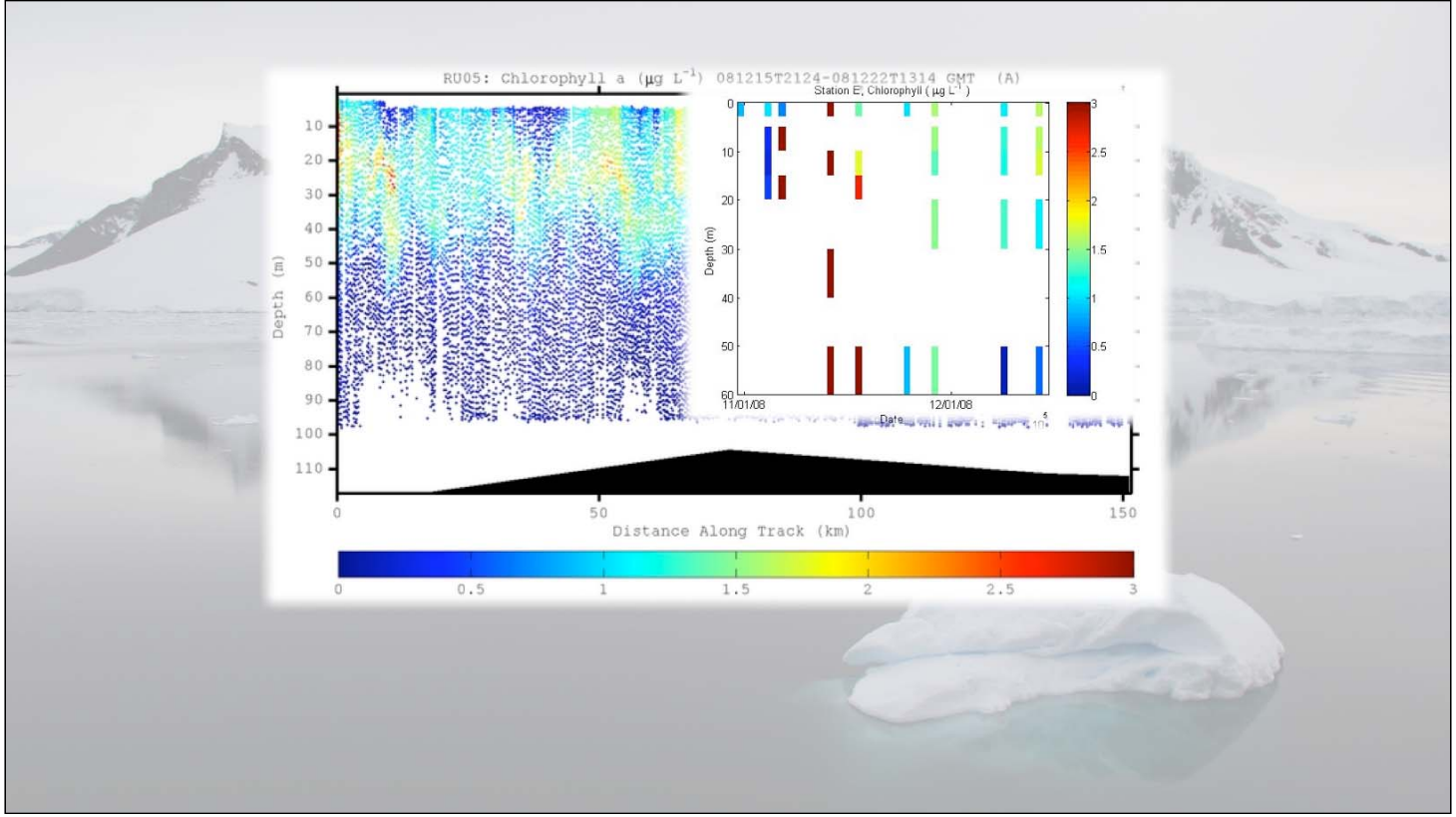


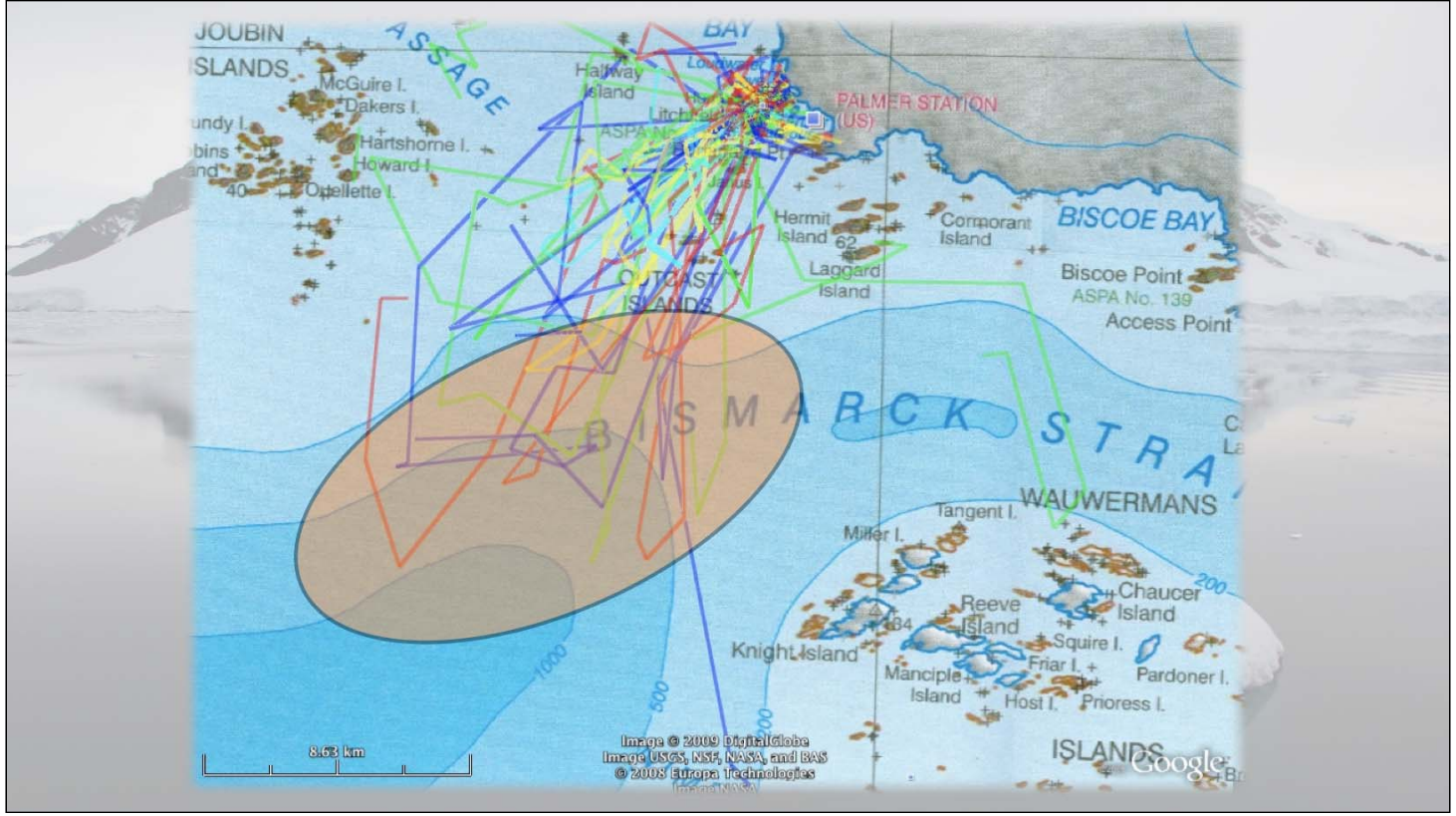


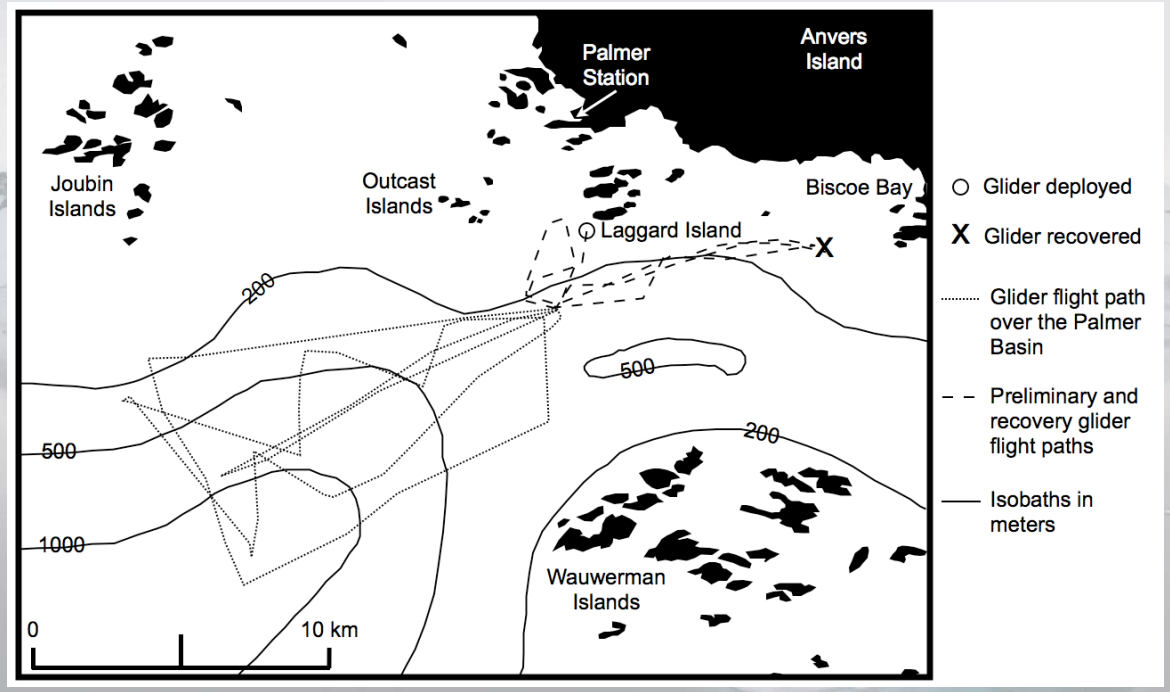
Timing of the sea ice extent



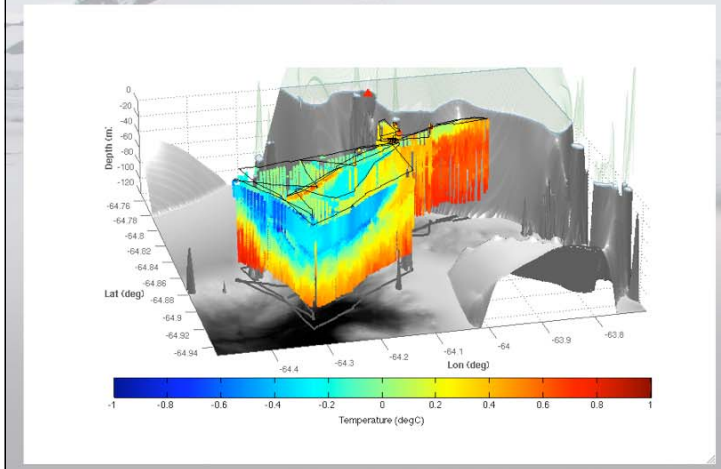

Station B, Chlorophyll (µg L-1)
Depth (m)
0
10
20
30
40
50
60
11/01/08
12/01/08
Date
x 10^5
3
2.5
2
1.5
1
0.5
0
Station E, Chlorophyll (µg L-1)
Depth (m)
0
10
20
30
40
50
60
11/01/08
12/01/08
Date
x 10^5
3
2.5
2
1.5
1
0.5
0

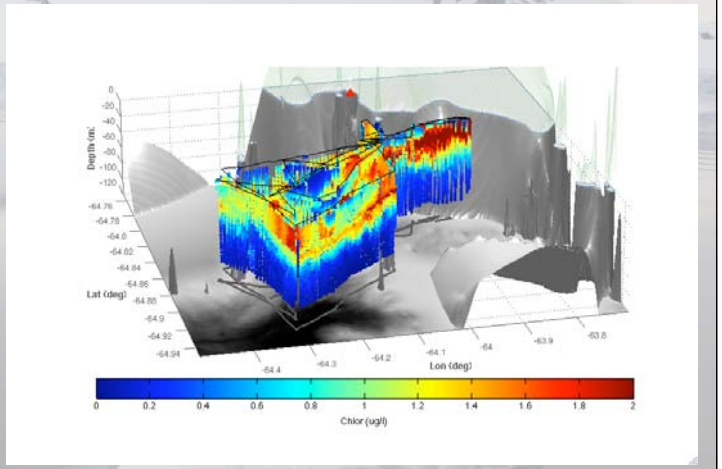

RU05: Chlorophyll a (µg L-1) 081215T2124-081222T1314 GMT (A)
Depth (m)
Distance Along Track (km)
Station E, Chlorophyll (µg L-1)
Depth (m)
11/01/08
12/01/08
Date

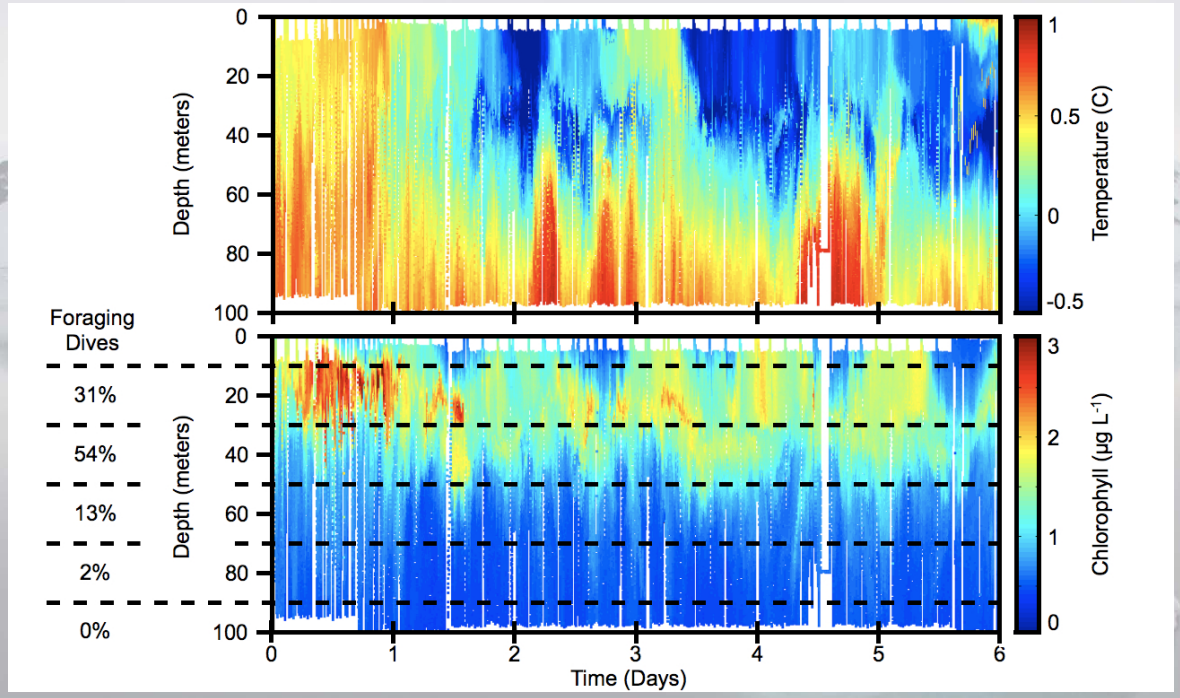

JOUBIN
ISLANDS
ASSAGE
BAY
McGuire I.
Dakers I.
Hartshorne I.
Howard I.
Otellette I.
Halfway Island
PALMER STATION (US)
Hermit Island
Cormorant Island
BISCOE BAY
Laggard Island
Biscoe Point
ASPA No. 139
Access Point
OUTCAST ISLANDS
BISMARCK STRA
WAUWERMANS
Tangent I.
Miller I.
Chaucer Island
Reeve Island
Knight Island
Squire I.
Friar I.
Pardoner I.
Manciple Island
Host I.
Prioress I.
ISLANDS
8.63 km
Image © 2009 DigitalGlobe
Image USGS, NSF, NASA, and BAS
© 2008 Europa Technologies
Google


Palmer Station
Anvers Island
Joubin Islands
Outcast Islands
Biscoe Bay
Laggard Island
X
200
500
500
1000
200
Wauwerman Islands
0
10 km
Glider deployed
X Glider recovered
Glider flight path over the Palmer Basin
Preliminary and recovery glider flight paths
Isobaths in meters

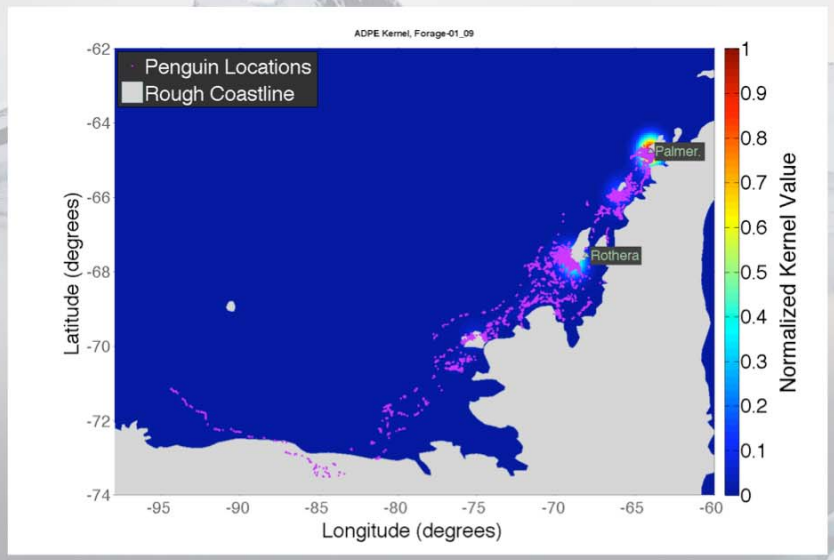
Enhanced productivity is associated with the warm upwelled water

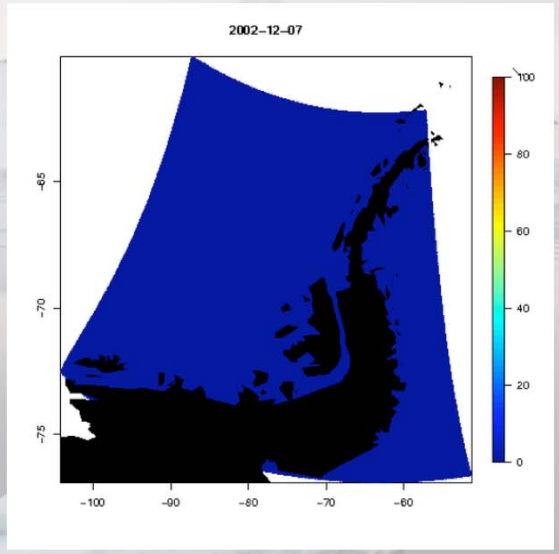





Depth (meters)
0
20
40
60
80
100
Temperature (C)
1
0.5
0
-0.5
Foraging Dives
31%
54%
13%
2%
0%
Depth (meters)
Chlorophyll (µg L-1)
3
2
1
0
0
1
2
3
4
5
6
Time (Days)

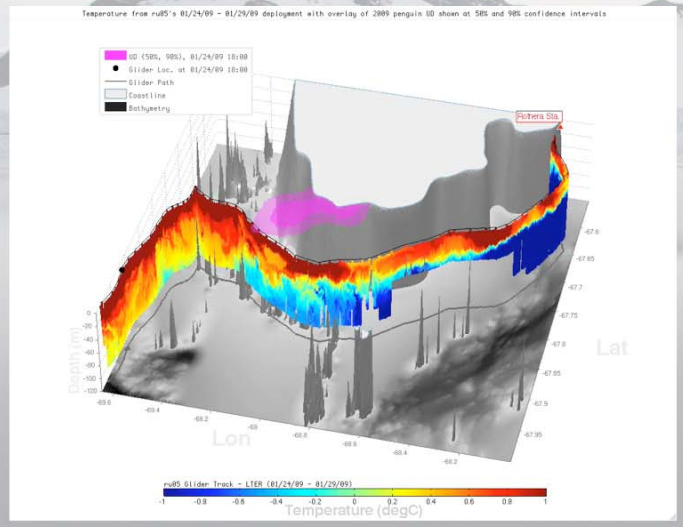
Using Bill's radio-tagged penguins define the kernel foraging and relate to the remote sensing data base

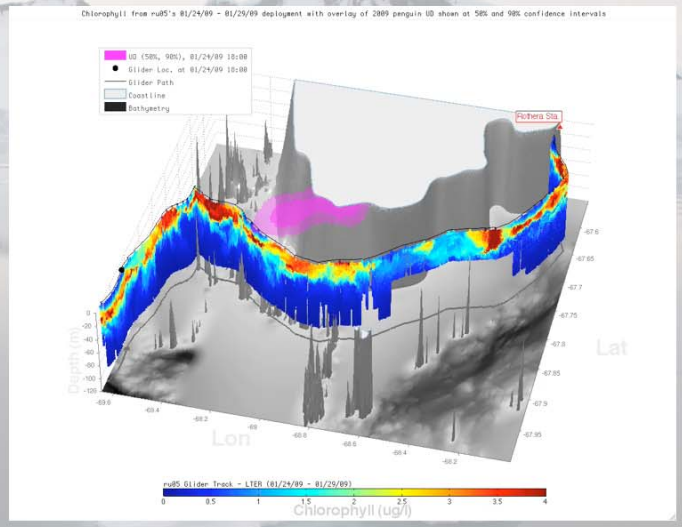




Adelie Penguin Pelagic Habitat Variation

Sea Ice Coverage (%)	SST (C)	Chlorophyll (mg/m^3)
0 - 27%	-0.2 - 2	0.07-2.4


Temperature from ru05's 01/24/09 - 01/29/09 deployment with overlay of 2009 penguin UD shown at 50% and 90% confidence intervals
UD (50%, 90%), 01/24/09 18:00
Glider Loc. at 01/24/09 18:00
Glider Path
Coastline
Bathymetry
Rothera Sta
Depth (m)
Lon
Lat
ru05 Glider Track - LTER (01/24/09 - 01/29/09)
Temperature (degC)

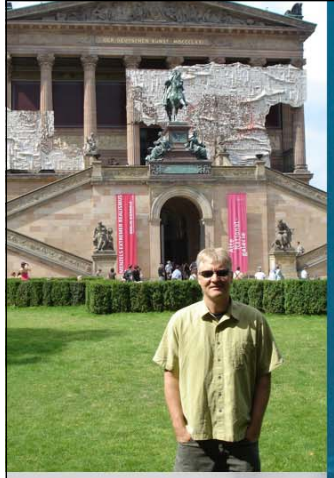

Chlorophyll from ru05's 01/24/09 - 01/29/09 deployment with overlay of 2009 penguin UD shown at 50% and 90% confidence intervals
UD (50%, 90%), 01/24/09 18:00
Glider Loc. at 01/24/09 18:00
Glider Path
Coastline
Bathymetry
Rothera Sta
Depth (m)
Lon
Lat
ru05 Glider Track - LTER (01/24/09 - 01/29/09)
Chlorophyll (ug/l)

Glider Operations for 2009-2010 field season

5 gliders in 2010 (& 1 in Amudsen and 2 in ROSS):

-1000 m meter glider, outfitted with CTD/backscatter/fluorescence
2 missions: First glider to be deployed in late November, fly to Rothera from Palmer. Survey will be looking for warm ACC water

- Four 200 m gliders. One glider outfitted with CTD, backscatter, chlorophyll and CDOM fluorescence. They will survey the canyon area prior to the RV gould arrival. The FIRE glider will be deployed at Palmer. As well as the ADCP glider. We will also add a REMUS (coming). One on the Gould.

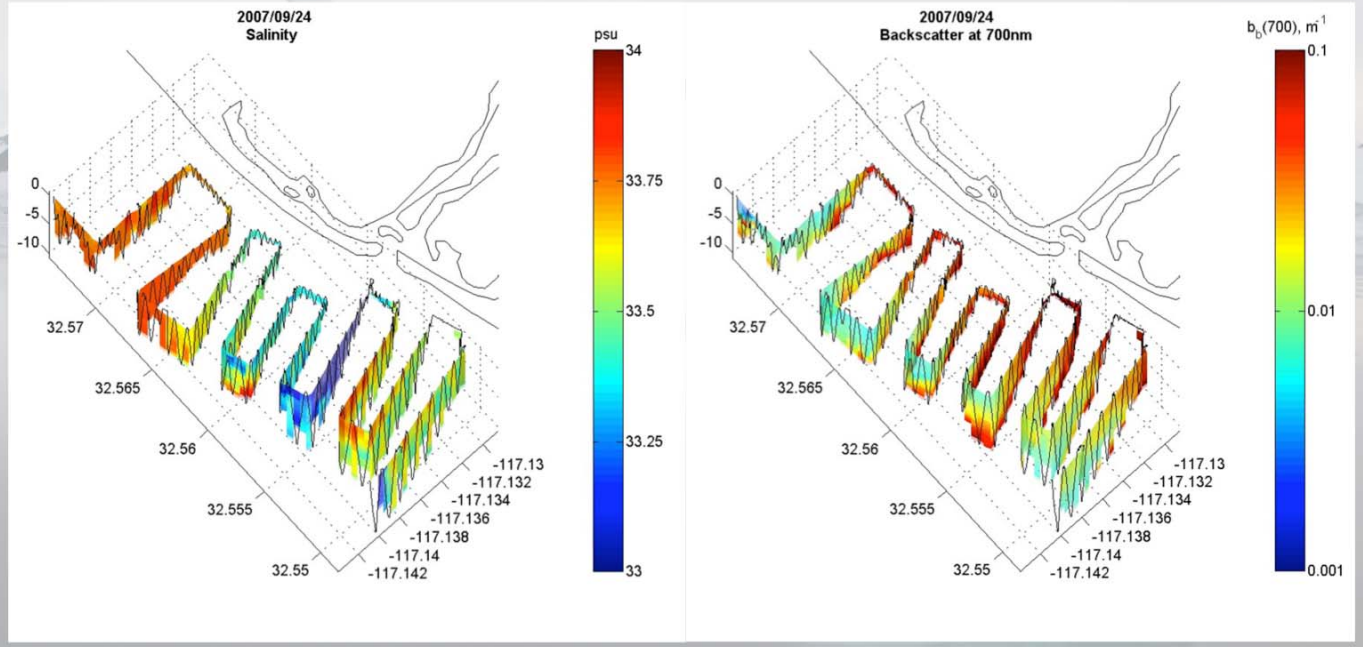


Moline SEGR : REMUS addition to Palmer efforts

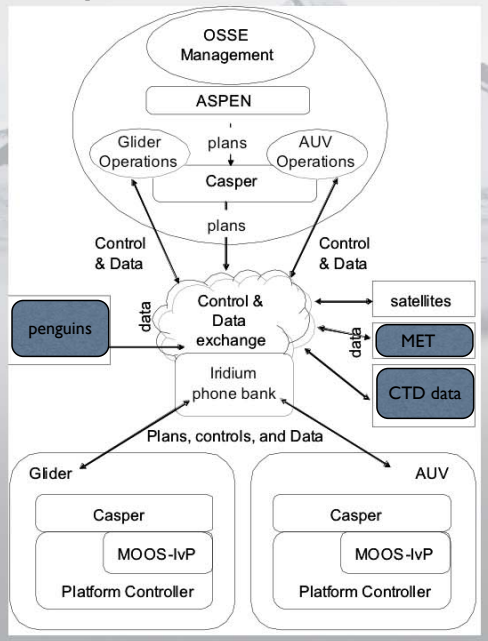
REMUS-100

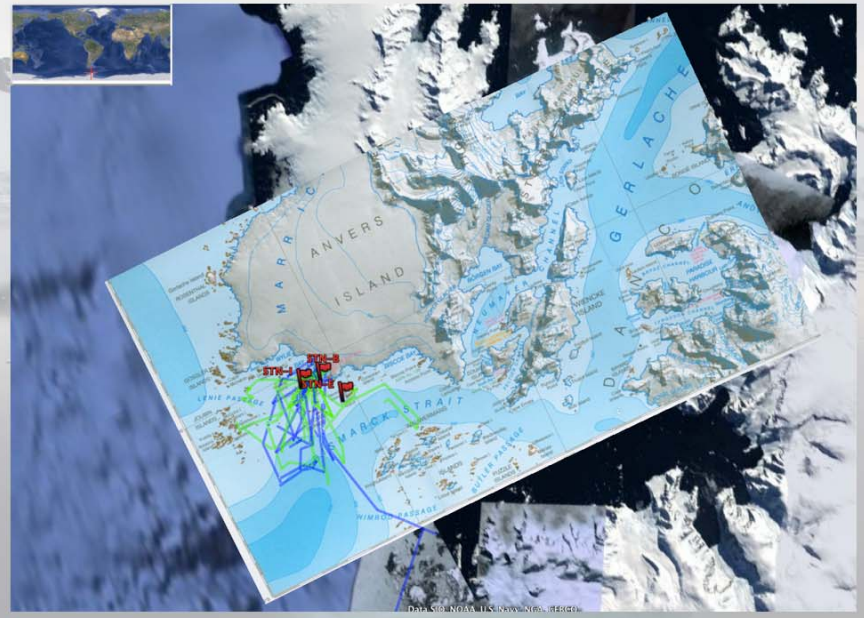
- CTD
- ADCP
- Altimeter
- Fluorometer

REMUS will provide high resolution volumetric data out over the canyon



OOI planning & prosecution cyberinfrastructure

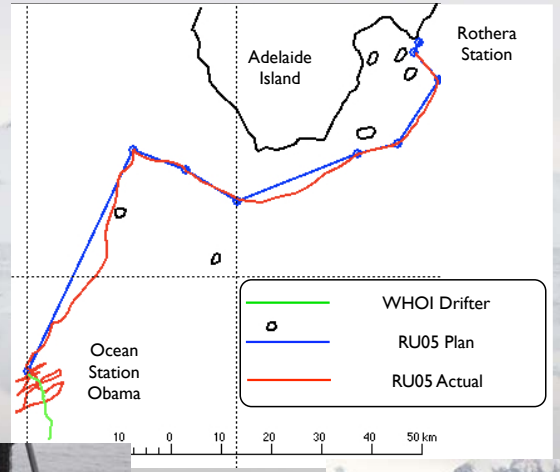




Old Day Communication

HAM Operator Coms Palmer Station 1988

Brave New Day



RV Gould

Rothera Base

Real time comms

Rutgers COOLroom

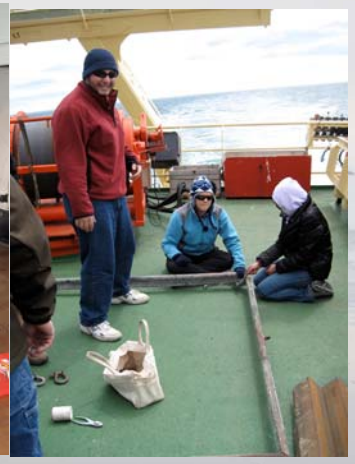
What is like working at sea?

We leave from Patagonia in southern Chile

Move onto ship

Unpack supplies and build lab

Tie everything down

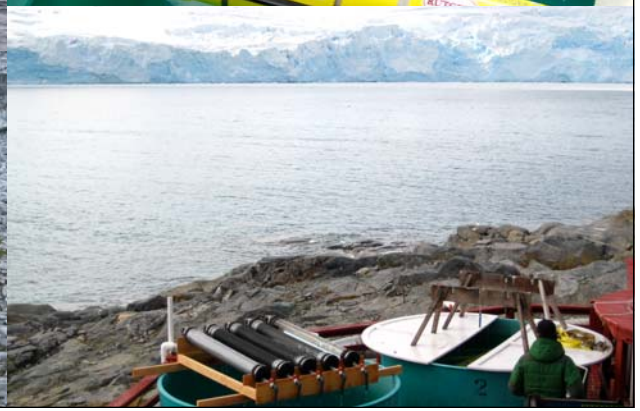


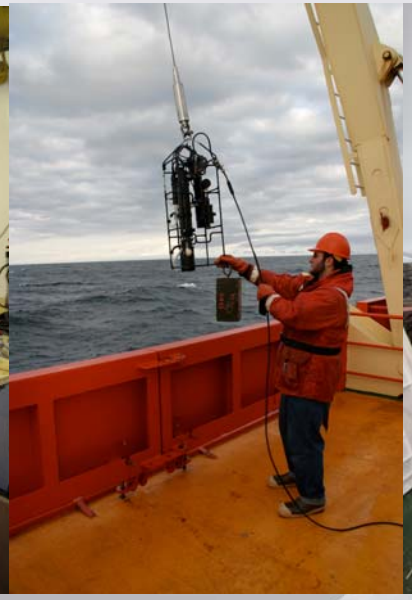
Build water equipment

The crossing is about four days, it is usually rough so you can't work outside. Alot of the people usually do not feel good.

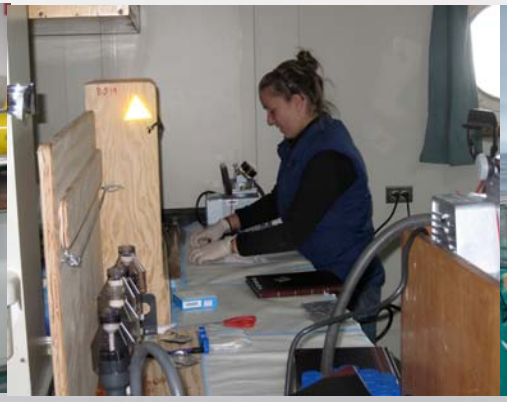
Welcome to Palmer Station

Living at station you work all the time, but the scenery and local animals are fun and not scared of humans



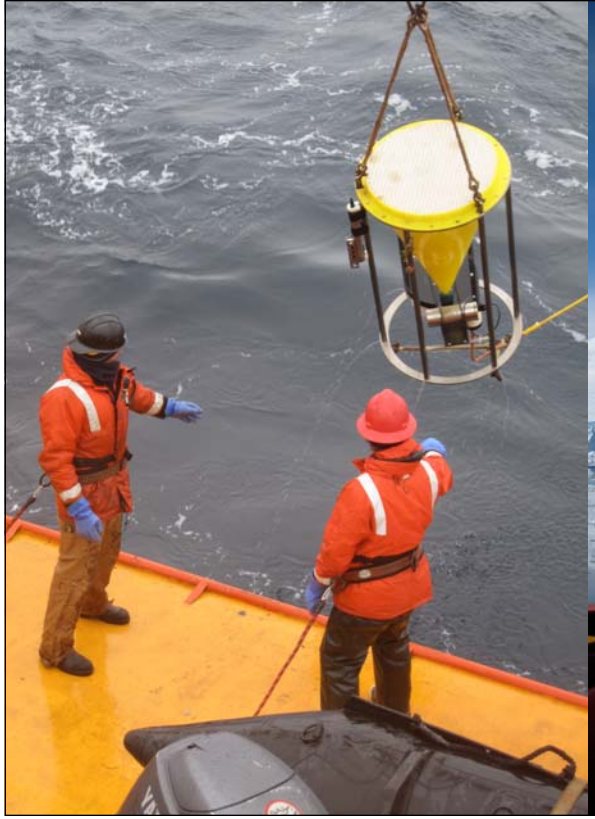




When ships starts sampling stations instruments are lowered each time. They are controlled from the ship.



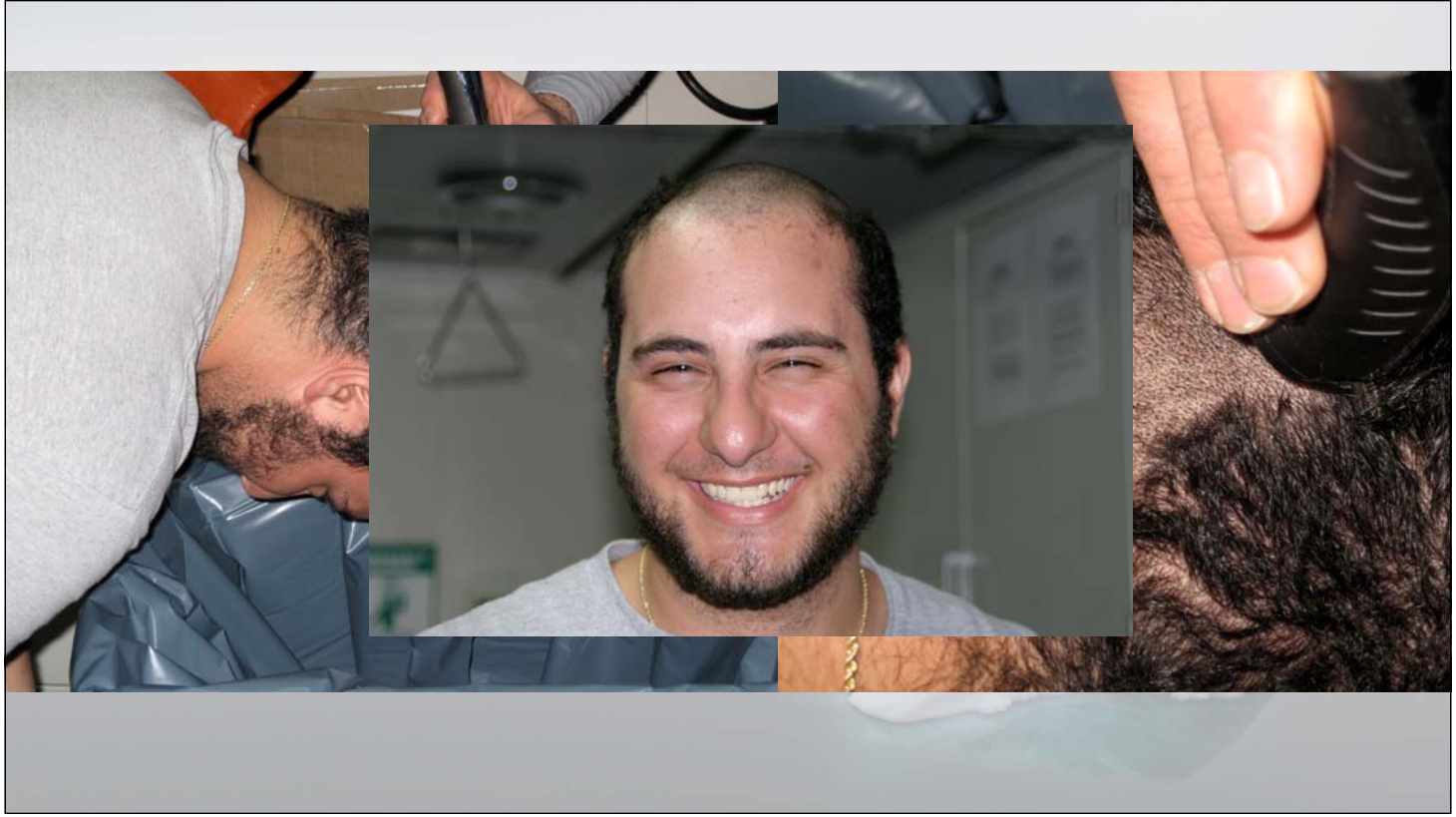
Water is collected, samples are then filtered for later biochemical analysis and some samples are incubated to provide a set of measurements.

Nets are deployed to catch animals



Moorings and sediment traps are deployed

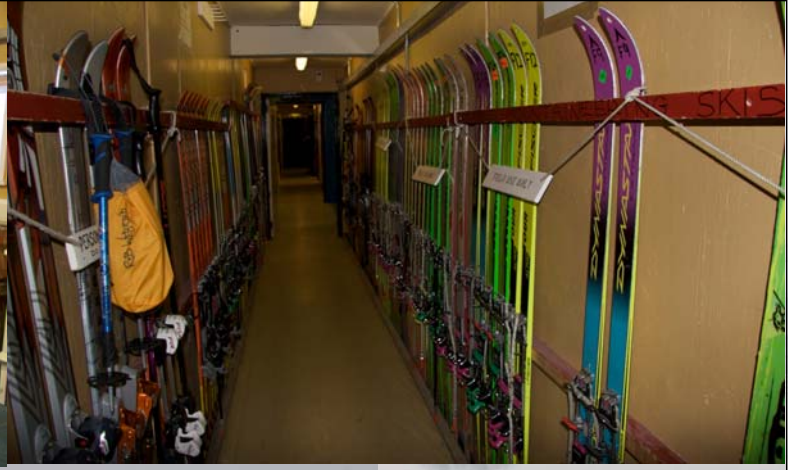
Good bye my friend,
I hope you come back




cerveza
AUSTRAL


Rothera Research Station
BRITISH ANTARCTIC SURVEY


Danger




FIRE EXIT